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By E. W. Allen, W. H. Beal, and E. R. Flint

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The year 1923 completed 35 years of operation of agricultural experiment stations in the States under the Hatch Act. That act, passed in 1887, did not become effective until the following year, because it was held to provide for but not to carry an appropriation. What it has meant to the organization of agricultural investigation is shown by the fact that it brought into existence experiment stations in 30 States and Territories which had not made provision for such activity, and that it gave definite form and support to several stations which had little more than a paper existence.

COOPERATIVE MAINTENANCE

The maintenance of the experiment stations represents a great cooperative undertaking between the Federal Government and the States, probably the most notable example of joint effort in the support of research to be found in any country or any field of science. Although no State contribution was stipulated, the participation of the States was implied by the fact that only a small percentage of the Federal appropriation could be used for buildings and none of it for land, and the necessity for added funds soon became so apparent that these were gradually provided in most of the States.

In addition to supplying a definite amount of money, provision was made for a central agency in the United States Department of Agriculture to have general supervision of the expenditure of the funds and to promote the interests of the stations, in the furnishing of aids to investigation, and in the stabilizing of conditions essential to productive research. The supervisory and advisory relations thus provided for by Congress was one of the first instances in which the Federal Government attempted to follow its funds into the States to see that they were devoted to the purposes originally intended and to promote that end through the activities of a central office. That the enterprise has been successful is attested by the position which these institutions have attained and by the notable advancement in knowledge of the principles and practices of agriculture in the past third of a century.

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Including the stations in Alaska and the insular possessions and some separate State stations, there are now 69 experiment stations in the United States and its outlying Territories and possessions, and of these 56 share in the Federal appropriation.

PROGRESS OF THE STATIONS

There was evidence of continued development during the year, which served to strengthen the stations and place them in the position of influence they formerly occupied. Increased support and a larger opportunity to strengthen their staffs and work was reflected in the demand for better preparation of workers, a further breaking away from conventional methods, and a raising of the standard of investigation to higher levels. As compared with the preceding fiscal year the total resources represented an increase of $1,360,000, and that derived from State appropriation or allotment showed an increase of nearly $638,000. This is highly gratifying in view of the great need for funds which the stations were experiencing, and evidences an increasing appreciation of their work on the part of the States and of the institutions with which they are connected.

The additional support, however, does not mean as much as it would if the growth for the past few years had been a regular one. During and following the war the support of the stations showed small increase, while the cost of operation grew rapidly. There was therefore an accumulated need of keeping abreast of the progress in other directions, and this has hardly yet been met. On the other hand, the new demands on the stations have grown to such an extent that it has usually not been possible to meet them except in a fragmentary way.

Evidence of growth is more strikingly brought out by a comparison of the past decade. Since 1913 the total resources have more than doubled and the amount of the States' support has fully trebled. The number of workers in the stations has increased by one-third, although there has been little or no advance in the direction of a separate station force. In 1913 approximately 47 per cent of the station workers were engaged in teaching or other college duties, and in 1923 the percentage was a little over 49. It is undoubtedly true, however, that there is much less teaching per worker and that it is more restricted to advanced grades, consisting in many cases of graduate work. There has been progress, therefore, in concentrating the energies of the station staff on research and the more advanced phases of teaching.

The regular publications of the stations have increased little in volume, although the number is somewhat larger. There are far less of the popular or extension character, and the publications are to a much larger extent based on the results of station investigations. The volume of work printed in scientific journals has grown greatly. There is no question that the published work of the stations shows a very material advance in fundamental character and originality.

These facts are the more noteworthy because of the interruption due to the war. They show that as a group the stations have resumed the growth and progress which were so evident prior to that time.

The unfortunate effects of inequalities are, however, apparent. A number of the smaller stations which are doing excellent work would be in position to render even larger service if they were more adequately supported. Financial stringency of the States has held down local support, and in some cases this has made it difficult for the stations to hold their best workers, and impossible for them to enter upon lines for which there was great need.

STABILIZING EFFECT OF THE FEDERAL APPROPRIATIONS

The benefit of the Federal appropriations has accrued not alone from the money supplied but from the stimulation which has come with it. These appropriations were responsible, in a large proportion of the States, for the original establishment of the stations, and the limitations surrounding the use of the funds have necessarily led to aid from the States. The supervision exercised, although designed to conserve the Federal funds, has aided in the development of policies which have been applied to all funds. This has had a far-reaching effect, especially in the earlier days, and it has freed the stations from interference detrimental to their efforts.

The Federal oversight has related not only to the actual expenditures but to the provision of conditions under which the moneys could be advantageously used, including a suitable personnel. As the stations grew, the standards and requirements pre-

scribed for those funds were widely applied to the organization as a whole. Hence the stabilizing effect of the Federal appropriations has been out of proportion to their size. They have not been subject to the fluctuations of appropriations in some of the States, and the measure of supervision and the character of the requirements have been uniform. Insistence upon a conservative policy of continuity in work has guarded against frequent shifting to meet temporary demands, and has emphasized the need for special appropriations by the States as these demands became urgent.

In the list of State-supported institutions, stations and substations have come and gone. Their work has grown to a certain point and then frequently suffered relapse. But the stations established under the Hatch Act have all been continued from the time of their organization and have represented a grade and a stability rarely to be found in purely local institutions. Sometimes neither the interest of a State nor the supervision of the Federal funds has proved sufficient to prevent disruption. Occasionally the stations are subject to a type of interference whose ill effects are not alone measured by the damage done at the particular time, but are difficult for the affected station to throw off.

The year 1923 witnessed a case of this kind of unusual severity, which illustrated how powerless public sentiment may be to afford protection. In the spring of that year control of the board of trustees of the Oklahoma Agricultural and Mechanical College was secured by removal of two members and appointment of others, following which the contract with the president of the college was abrogated and he was summarily removed without being permitted to serve out the college year. Following his overthrow a successor was appointed whose suitability was vigorously challenged, and a considerable number of department heads in the college and experiment station failed of reappointment. Others resigned because they believed every condition was against them, and that the tenure of their position was only limited by the ability to find a successor. The director of the station was among the latter, and the position of dean and director was combined to fill the gap. As could hardly be otherwise, the station work and forces were demoralized and its long-time investigations were jeopardized.

As is usual in such cases, the station was the first agency to be affected, and the effects were more far-reaching than in any other branch of the college. The failure of those responsible to realize the damaging effects and the inevitable setback to the agricultural interests of the State was the most discouraging aspect of the situation. This discouragement was intensified by the fact that the experience of the State in the past has failed to teach a lesson. Since 1900 there have been 10 changes in the directorship at the Oklahoma station, which alone illustrates the impossibility of any fixed, continuous policy; and these, with the many changes in the staff, have resulted in projects upon which much money has been spent becoming well-nigh sterile. Little progress could be made in these from one period to another, and the frequent change in leadership sometimes resulted even in losing sight of the original objective.

Eventually public sentiment did assert itself in this case sufficiently to cause another change in the board of trustees for the purpose of rescinding the action of the previous board. The college president, who had been in power only a few weeks, was dismissed, and the new board refused to retain in office several others who had been identified with his administration. This could not undo the harm which had been done, and served for a time to perpetuate the confusion and uncertainty; but it soon became evident that the board was taking steps to remedy matters as far as possible by the selection of a suitable president; and this, with the placing of the institution on a proper fiscal basis, paved the way for reconstruction. This unfortunate situation left no course open to the department except to withhold the Federal funds pending readjustment; but certain amounts of the Federal funds which had been improperly used were refunded, and the station program was revised and placed on a more promising basis. Following this the funds were released in the hope that this experience was sufficient to bring about a realization of the requirements of a successful and efficient station and to increase its immunity to danger from such disrupting influences.

Fortunately, such conditions are very exceptional. For the most part there is understanding of the dangers which may come from disturbing the well-being of the station and either disinclination or apparent hesitation to take any steps which may lead in that direction. There is wide-

spread appreciation of the stations in all the States, with a strong, aggressive support which would resist harmful influence. Almost universally the stations have made steady advancement in the past few years in strengthening their forces and their work and raising the level of their investigation.

STATE ADMINISTRATIVE CONTROL

There has sometimes been apprehension, mainly on theoretical grounds, lest centralized Federal supervision dominate the local authority in the management of federally aided institutions. Curiously enough, this apprehension has found less expression in relation to research than some other branches of activity, although it might well be contended that research is, of all types of activity, the one whose freedom is to be the most carefully guarded. But the purpose of the relationship of the United States Department of Agriculture to the State experiment stations has become so established as apparently to allay apprehension, and often it has been welcomed as supplying an element of restraint from interference of another type.

A few of the States have instituted administrative supervision affecting not only details but extending to essential features of policy. Federal allotments have been budgeted with the other resources for similar purposes, and subjected to the same limitations and rules and the same intimate control. Nothing in the line of Federal control has approached this supervision in degree or character, and the extension of it has come to be looked upon as a menace to the institutions.

One form this control has taken in several States has been the subdividing of appropriations in great detail so as to fix the amounts which might be used for salaries, for labor, for various classes of supplies and apparatus, and even for the support of individual projects. Not alone the total salaries but those of individual workers have been made statutory, and the amount which might be spent on a given project has been fixed in the appropriating act on the basis of estimates made long in advance and covering a biennial period.

Although the control is confined mainly to finances, it frequently affects directly the details of the work. It supersedes the authority of the director of the station, the dean, and even the president of the college, in matters which are of very vital importance. Decisions are made by fiscal agents located at the seat of government, clothed with large authority, but lacking an understanding or appreciation of the special requirements. The type of control to which there is objection is not exerted through an audit, but by the making of regulations and restrictions, by the setting up of procedure which leaves little to the discretion of administrative authorities and which makes small provision for unforeseen emergency, such as is very apt to arise in an experiment station. In one State, for example, after money has been appropriated by the State or received from the Federal Government, no branch of the college may establish a new position, fill a vacancy, or increase a salary, no matter how great the emergency, without recourse to a State board of administration. Unless supplies, equipment, and apparatus have been estimated for in advance, the station may not make purchases necessitated by unforeseen contingencies in connection with the progress of its investigations. This control extends even to the matter of travel, printing, and the kind of matter which may be published.

Numerous States have imposed restrictions on travel, or regulations which operate to take the decision out of the hands of the local authorities. In a number of cases station men can not travel outside the State except on approval of the governor or State administrative officer at the capitol, to obtain which frequently involves much delay. In six States provisions of law require the approval of all printing, as to quantity and the character of the matter, by State authorities not at the college. The unwisdom of such a course when applied to the results of scientific investigation must be apparent if the provision becomes more than a routine procedure. Not only does it make possible the control of the form of publication, the illustrations and tabular matter to be incorporated, and the detail and length of presentation, but it places in the hands of such censors the determination of what may and what may not be published by the station. The latter is exactly what has been done in a number of cases. Manuscripts from the experiment station have been rejected because they were regarded as too technical or were not thought to be in the interest of agriculture, or they have been edited until they failed to meet their purpose. This will be recognized as one of the most serious forms which State supervision could

take, unless it is exercised with the greatest liberality and large reliance is placed upon the judgment of the administrative officers at the institution.

Where the Federal funds are exempt from State supervision they give a measure of freedom in meeting actual requirements. This applies also, for example, to travel outside the State and to publications, some stations doing all of their out-of-State travel and printing all or most of their publications with the Government appropriations. Where permitted, the Federal funds have sometimes been used to supplement the State appropriations for salaries, enabling a class of workers to be retained who would otherwise be lost to the institution. In some cases, however, regulation of expenditures by State officers is becoming so drastic as to hamper the use of Federal funds, which are paid in advance in order that the stations may have a working capital to meet necessities as they arise. Under the law they are paid to the colleges as the institutions designated as the beneficiaries by the States in their original acceptance of the acts.

Although the States undoubtedly have a responsibility as regards the use of the Federal funds and are fully justified in a form of audit which will guard these responsibilities, there would appear to be no warrant for setting up procedure which will interfere with the proper use of these funds under the Federal laws or place the station at a disadvantage in carrying out its plans for research after they have been approved by the constituted station authorities and by this department.

TREND OF THE STATIONS

From one year to another there is little material change to be noticed in the general course of the experiment stations, but from one period to another certain tendencies make themselves apparent. These are developments which may lie within the organization, or they may trace their origin to considerable extent from without, as a result of conditions developing in the parent institutions.

For several years there has been a movement in the direction of sifting the problems of individual stations, a going over of the list of projects with a view to determining their relative importance at the present stage and deciding which should be brought to a close or given a somewhat new direction. This has proved a profitable undertaking for a number of the stations. The taking account of stock has proved helpful in determining just what point has been reached and the prospect and desirability of further continuance. Sometimes such a review brings out the need for some cooperative or supplementary work, and again it may show how the work can best be rounded out for completion.

With respect to the outlying work, the present tendency is in the direction of more temporary facilities, the local studies, whether done by field workers or the experts, to be reinforced by investigations in the laboratories of the main station. This is a notable advance, for it husbands the stations' resources while providing for investigation of problems where they exist in typical form, and makes it possible to serve the State more thoroughly and systematically.

Increasing emphasis is laid on the laboratory side of investigation or study conducted under laboratory control. This serves to supplement and to some extent to replace reliance on gross experiments in which only part of the conditions are known or can be controlled. The broadened and deepened outlook which advance in science has given has shown the complex nature of many problems previously thought to be simple, and has made it possible to view and approach them from different angles. The quick answer which the field experiment or the feeding trial was formerly expected to give has been shown to be subject to variation and less reliable than was assumed. The trend toward fundamental research based on an exact knowledge of conditions and the study of relationships is one of the notable advances in the work of the stations. This trend has been particularly conspicuous in the past few years, even while the stations were laboring under financial stress, and already such research has yielded results whose practical value needs no defense.

There is much more marked attempt to take account of what others are doing and have done, to build on what research has already suggested or taught, and to maintain contacts which will give familiarity with these things. It is only a step from this to arranging for coördination in studying complicated problems, and even to entering into more or less definite cooperation. Cooperation has been promoted by a number of large cooperative projects conducted by this department, some regulatory or repressive, and others involving investi-

gation, which have demonstrated the advantage of cooperation and done much to allay doubt as to its feasibility. Cooperation between the Federal department and the experiment stations has steadily increased and is now of large proportion, involving many thousand dollars and a long list of diverse projects.

No station exists to itself or relies exclusively upon its own efforts in solving the problems it has to meet. Community of interest, which finds expression in a variety of ways, is having a steady influence on the work of the whole group of stations. Attendance at scientific meetings where there is opportunity for comparison of notes, exchange of views, and the enlargement of acquaintance, has been no small factor in attaining this end.

In general, the tendency is to publish the results of research at the stations more promptly than was formerly the case. This is helped by the use of scientific journals, especially in the making of preliminary announcements and reports of progress when a significant stage has been reached. The more scientific results are thus made promptly available to others, and opportunity for criticism or discussion is offered. The increased volume of published work makes for the growth of knowledge and its use over a broader field, and helps toward the fuller solution of questions of practical importance.

The type of station workers required has undergone a steady change. The demand is now almost universal for thoroughly trained men with graduate study which has broadened their view of the field of science and instilled in them the spirit and methods of science. Many of the less mature workers in the stations arrange to go away on leave of absence for advanced study, frequently on favorable terms on the part of their station, and the younger men coming into the work have been led to see that graduate study is essential to their advancement.

Frequently the work of graduate students is fitted into the station investigations. There are many cases where such students are enrolled in the station as graduate assistants, doing part-time work with opportunity for their studies. On the other hand, the graduate work of the colleges with which the stations are connected has been systematized and enlarged. The end sought is in every way desirable.

There are, however, certain possible dangers to be guarded against, such as overreliance upon that class of help and the retardation of established projects. The station can ill afford to be dependent upon such help for its primary functions, although it often may employ graduate students to the mutual advantage of itself and the students. A blending of the experiment station with the graduate school, however, is not implied; undue dependence upon graduate students might soon rob a station of the independence and self-reliance to be looked for in a research institution having its own aims, resources, and responsibilities.

Another factor to be considered in the preservation of station individuality is the union of station administration with that of other branches of the college. Unless provision is made for an officer of experience in charge of research, with time to study the work of the station, to counsel with and promote the efforts of its workers, and to maintain the necessary contacts within the college and outside of it, the station may decline in aggressiveness and unity of purpose. Other branches are aggressive and have within themselves means of keeping their interests before the authorities and the public.

The station is more than an aggregation of independent departments held together by a name. There is a legitimate and useful place for administration in connection with organized research, and the effective use of public funds calls for a type of study of the field which is not supplied by the individual specialists. A trend away from this, with a minimizing of organization and administration, is not in the direction of preparation for larger support and responsibilities.

IMPORTANCE OF LONG-TIME PLANNING

The attempt to work out a general program covering a period of several years has commanded the attention of several stations. The long-time plan was the subject of a report to the Association of Land-Grant Colleges during the year, by its committee on experiment station organization and policy. Its purpose is to anticipate future development in order to organize the whole effort of a station so as to make provision for its essential parts, minimize the danger of premature interruption, and expand in accordance with a studied plan.

Sooner or later every growing institution outlines such a program. No station can do everything it would be desirable to do, but out of the vast

range of possibilities it must select certain lines and subjects which are primarily worthy of attention. This will affect the building up of a personnel and special facilities for research, and it will serve to bring out more definitely the financial needs. By such means a station may express to the authorities of the college and to the public its mature judgment of the field it ought to occupy and what this would involve.

Consciously or unconsciously the individual stations have been evolving such programs with more or less definiteness, which are expressed in a way by their organization and the list of projects they are pursuing. In the past the plans have usually been of shorter range, and to some extent they have reflected the composition of the personnel, the existing facilities and funds. To an extent this may even have been unconsciously reflecting a public demand, a changing view, or personal preference.

Investigation is rarely a matter for this year or next. It requires a considerable period of time, and at the present stage it needs to be projected so as to be thorough and conclusive. It attacks one point after another in the working out of a problem, the attack changing with the progress of the study but not losing sight of the main objective. An illustration is supplied by the Adams fund projects, outlined with a definite purpose and initial plan of procedure, but subject to modification as the study advances, and designed to continue without interruption until a conclusion or a definite stage of advance has been reached.

A station should not fail to be responsive to the needs of its community, but it can not afford to pursue a vacillating course or to have its work represent fragmentary effort. Its program naturally would be related to the matters of primary importance to its locality, and it should not be so formal or fixed as to omit provision for meeting emergency questions. It would not undertake to be a formally crystallized plan, all-comprehensive in its nature and inflexible in its provisions, but would be designed to serve as a general guide in the administration, development, and financing of the institution. It should never be so inflexible as not to admit of improvement by amendment as new workers and new ideas become available to the station, but, on the other hand, it ought not to be interrupted or abandoned because of changes in personnel or as a result of personal preference of workers. Although opportunity should be preserved for the exercise of initiative and reasonably wide range of freedom in research, such a long-time program would encourage the individual by contributing a larger measure of security for his investigation, and would guard against his needs being overlooked in the annual budget and plans. This might give an added feeling of advantage and permanence among workers which would often reduce the frequency of change from one institution to another, especially among the more mature members.

Evidently such a program should be general rather than detailed, and should be subject to revision from time to time as circumstances require. But it would have a substantial background in a broad study of the situation and represent a conscious effort to weigh and adapt the various lines of effort in accordance with their merits and relative importance. It would tend to direct the policy of the station along well-defined lines, and in many cases it would have reference to the station as a whole rather than to separate departments.

The idea of the unity of a station is essential to the making of any well-rounded program. An experiment station can not be viewed merely as an assembly of departments, but rather as a union of effort in which various departments are embraced. These departments are interrelated and drawn together by community of interest in broad questions. Their relationships are more easily discovered and the objective of the station more readily attained if there is encouragement to think beyond the immediate boundaries of individual departments, and this would be an inevitable result of the construction of a long-time program. Moreover, owing to the dependence of stations on one another in working out the agricultural problems of a given region, each institution needs to take into account the activity of other stations in that region. This can be most successfully done if each station has a fairly definite program mapped out for its main lines of research.

One prerequisite in attaining such an end is a definitely assured budget. Under a system of annual or biennial appropriations this can not be absolute, but standing appropriations, or apportionments which make for stability, are becoming more common. The cost of making investigations in

a continuous way and on an assured basis of support is far less than by intermittent and uncertain effort, and results are more sure to follow.

VISITATION OF THE STATIONS

The office has maintained the usual close relations with the experiment stations of the country throughout the year. In addition to its correspondence, its approval of Adams fund projects and programs and the examination of the financial reports, it has been brought into direct contact with all of them through official visits of members of the staff. These examinations on the ground have been participated in by the chief and by W. H. Evans, W. H. Beal, E. R. Flint, and J. I. Schulte.

The advantage of this close contact is seen in the intimate view which it gives of the station work and management, enabling a more just interpretation of the use of the Federal funds. It has helped materially to maintain good relations with the individual stations, and to avoid misunderstandings on either side. The attitude of the local institutions and their authorities toward the Federal supervision has been uniformly cordial and helpful in every way.

LEGISLATION AFFECTING THE STATIONS

Legislative action affecting the experiment stations, aside from appropriations and provisions for new buildings, which are noted elsewhere, was not very extensive during the year.

The California Legislature of 1923 transferred the Laboratory for the Biological Control of Insects from the State department of agriculture to the university, and included $50,000 in the general appropriation of the college of agriculture to maintain the work for two years. Provision was also made for an increase in salaries and maintenance of all college and station activities, which was offset in part by a reduction of $40,000 a year in the income from university endowments available for college and station work.

The preceding legislature of Colorado had provided for the grading of fruits and vegetables, which was assigned to the station. This caused some dissatisfaction, and the last legislature passed a law authorizing voluntary grading by the State, and put it in the hands of a special officer directly under the governor. A bill was passed appropriating $10,000 for the purchase of land and equipment for the Greeley Potato Station, which is being managed by the Bureau of Plant Industry, U. S. Department of Agriculture. An appropriation of $4,000 was also granted for the purchase of land and equipment at the Cheyenne Wells branch station.

The 1923 General Assembly of Connecticut increased slightly the appropriations for the State station, for general maintenance, insect-pest control, white-pine blister-rust control, and gypsy-moth control, and doubled, from $5,000 to $10,000 annually, that for the support of the tobacco substation. An increase from $17,500 to $30,000 was made in the annual appropriation for the Storrs station, for maintenance, which will greatly strengthen the work now under way and allow for a small expansion, notably the inauguration of work in agricultural economics.

A recent session of the Delaware Legislature passed a bill authorizing the control of all expenditures for supplies to be vested in a State board of supplies. The annual appropriation of the station was reduced from $20,000 to $17,500.

In Kansas, the responsibility for the enforcement of the fertilizer, feeding stuffs, and livestock remedy laws was transferred from the experiment station to the State board of agriculture, although the chemical analytical work will continue to be done at the station. A new feature was added to the work of the station by the appropriation of $6,000 a year for the current biennium to finance outlying experiment fields in southeastern Kansas. This was secured as a substitute for a proposed new branch station. These fields will be supervised from the main station, and but little overhead expense will be involved, especially for building and equipment. Five fields have been located for soil and crop problems.

In Minnesota, the legislature increased appropriations for work on soils and discontinued those for investigations on drain tile and cornstalk sirup, the above not becoming effective until the fiscal year 1924.

The Montana Legislative Assembly reduced the appropriation for grasshopper control from $3,900 to $500, which was further reduced to $450 when the governor approved the bill. This unfortunately occurred when the State was in the worst grasshopper outbreak it had experienced for 50 years. The legislative assembly for 1923 revised the insect pest law by authorizing the county commissioners to expend and assess back on all county property not to exceed 1 mill,

instead of one-half mill as previously provided.

In New York the legislature of 1923 passed a law whereby, beginning July 1, 1923, the administration of the State station at Geneva passed into the control of the board of trustees of Cornell University and Dr. R. W. Thatcher was made director of both stations, the Geneva station, however, to remain as an individual unit, with its own series of publications. An act was also passed providing for horticultural investigations in the Hudson River Valley, with appropriations for the same, and giving the board of control of the State agricultural experiment station authority to rent suitable land and buildings and to employ the necessary staff. Special appropriations were also made for vegetable research on Long Island.

The last legislature of Oklahoma passed a law placing a registration fee on fertilizers, the greater part of which will come to the station.

New legislation in Oregon included an economic poison law "to provide for the regulation and manufacture and sale of any substance or mixture of substances intended to be used for preventing, destroying, repelling, or mitigating any and all insects, fungi, weeds, or other plant or animal pests, collectively and individually, which may infest or be detrimental to vegetation." The director of the experiment station is made responsible for the administration of this law.

The Texas Legislature, in passing the general appropriation bill, providing financial support for the Texas station system, removed the restrictions and intense itemization which were formerly placed on the bill, greatly improving the situation as to efficient administration. A State board of control was also provided for which also serves as the board of directors for the State eleemosynary institutions. This board has charge of the printing and purchasing for all State institutions, except that the station is exempted in the case of scientific materials. A new substation for the Rio Grande section was provided for with an appropriation of $25,000 a year for two years.

In West Virginia the legislature provided a sum of $5,000 for buildings upon the Reymann Memorial Farm at Wardensville.

The legislature of Wyoming, of 1923, passed a bill creating a new department of agriculture, to have control of State farms; State dairy, food, and oil department; and the State department of immigration, as well as to take on other duties including general police power in matters relating to agriculture. According to the law, the director of the experiment station of Wyoming is a member of the board of agriculture ex officio. A. D. Faville, former director of the station, was appointed first commissioner of agriculture. A law was also passed abolishing the agricultural advisory board, which had previously had control of the State farms. These were turned over to the board of trustees of the University of Wyoming, with an appropriation of $24,000 to operate them during the biennium. This is the final step in placing the so-called State farms branch stations under the management of the director of the experiment station and the board of trustees..

ADDITIONS TO BUILDINGS AND EQUIPMENT

Important improvements in station equipment, including buildings and land as well as scientific apparatus and laboratory supplies, were made during the year. In a number of States new buildings were provided, either wholly for station use or for combined college and station occupancy. The limited land at the disposal of some of the stations was increased by the purchase of additional acreage either adjacent to the station property or as outlying farms. In many cases additional equipment and buildings were provided at the branch stations, and in some States provision was made for additional stations, thus largely extending the opportunities for investigation under varying local conditions. The more important additions to buildings and equipment were as follows:

At the Alabama station a tract of 55 acres was added to the farm and an option was secured on an adjacent farm of 400 acres. New greenhouses for the agronomy department were completed and put in use, a new animal pathology building was nearly finished and partially occupied, and anatomy and clinical buildings were erected.

The Arizona station reported the addition of considerable apparatus and equipment, and extensive additions to the poultry plant, including an incubator cellar, egg-laying contest houses, and breeding houses. Two dwellings and a pump house were also built. At the substation at Yuma a poultry house and yard, corral, and shed were added.

The Arkansas station lost by fire the main barn, dairy barn, and stock-judging pavilion.

In California, at the university farm at Davis, the new dairy industry and horticulture buildings were completed and occupied. An agronomy warehouse, a pomology packing house, a wool laboratory, and a water tank of 100,000 gallons capacity, providing irrigation for 105 acres, were also added. At the Riverside station, greenhouses were erected, and frost protection provided for 60 acres of citrus orchard. The transfer of the Laboratory for the Introduction of Beneficial Insects from the State department of agriculture brought to the university the equipment housed in a six-room laboratory at Whittier.

At the Colorado station, the old chemistry building, destroyed by fire in 1921, was reconstructed on the old foundation, at a cost of $70,000, to be occupied by the station departments of chemistry and botany. An experimental Venturi flume was built at Bellevue, and a small building was rented and equipped as a chemical laboratory at Rocky Ford.

At the Connecticut State station, an experimental tobacco-curing barn was built at Windsor, and two insectaries were constructed at the main station. At the Storrs station, a large shed was built for steers and supplies for pasture experiments.

In Florida 30 acres of land was contributed by the citizens for the tobacco branch station at Quincy, and a brick laboratory costing about $12,000 was completed.

At the Georgia station, the sweet-potato storage house, which was destroyed by fire, was replaced. A greenhouse for plant disease work was constructed during the year.

The Illinois station secured $50,000 for a beef-cattle barn and equipment; and a respiration chamber, to cost $3,500, with equipment, is to be added.

At the Indiana station a farm of 422 acres about 2 miles from the campus was purchased for the animal husbandry department, and the station was given the use for an indefinite period of an 80-acre farm near Salem, in Marshall County. A new poultry building, to cost $8,600, was started, a new sheep barn with feeding pens was constructed, and the house on the horticultural farm was remodeled.

The Iowa station acquired a tract of about 100 acres of fine farm land, adjacent to the dairy barn, for the use of the dairy husbandry section, and a farm of 165 acres southeast of the campus was purchased for use by the horticulture, forestry, landscape architecture, and truck crops sections. New horse and sheep barns, a poultry laboratory building, a hollow-tile hog house, and a model farmhouse on the agronomy farm, to replace one destroyed by fire, were completed during the year. The station barn was destroyed by fire in 1922 with an estimated loss of $25,000.

At the Kansas station the new wing of the agricultural building, to cost $275,000, was nearly completed. The first floor will be occupied by the dairy department, the second by the poultry department, and the third by agricultural economics, and a one-story extension on the court is to be a meat laboratory.

The Kentucky station acquired a considerable tract of land in the eastern part of the State for experimental work in agriculture and forestry, through the gift of E. O. Robinson of Fort Thomas.

Beef-cattle, dairy, and hog barns were completed at the new site of the Louisiana University and station.

The new chemical building for the Massachusetts station was nearly completed. This will house all of the chemical research, the old chemical laboratory being used for control work. Additions to the poultry plant included three unit laying houses for 600 pullets, a cockerel house, and a house for year-old hens, costing from $5,000 to $7,000.

The Michigan station received $400,000 for a new horticultural building, to be partly used for station work. A new piggery, costing $8,500, and a 3,000-bushel capacity root cellar were added to the equipment.

At the Minnesota station, a new dairy building, to cost, with equipment, about $250,000, was under construction and partly occupied for experimental work.

The new biology building at the Mississippi station, costing $250,000 and to be used in part for station work, was nearly completed. Other additions included some minor buildings and repairs on the farm, and a fireproof storage room for publications.

At the Missouri station, the new agricultural building, costing about $200,000, was nearly completed and partly equipped during the year. Agricultural engineering was transferred to the building formerly used by the poultry department. A new beef-cattle barn was completed at a cost of $25,000, and a new and modern

refrigerating machine was installed in the dairy husbandry department.

The new biology building at the Montana station was completed and partly occupied by certain departments of the station. A refrigerating room for controlled constant temperatures was added. Some improvements in buildings were also made at the Horticultural, Judith Basin, and North Montana substations.

A beef-cattle barn with experimental feeding sheds was erected at the Nebraska station, and a cement-floored feed lot was built at the agronomy farm. The poultry plant at the central station was relocated and new buildings erected.

The New Hampshire station added a number of larger pieces of apparatus to the laboratory equipment.

The poultry husbandry building at the New Jersey station was completed and equipped at a cost of $90,000, and was occupied during the year. Several minor buildings were erected, and substantial additions were made to the dairy herd.

At the New Mexico station, a new greenhouse was completed and an implement and storage shed was built on the horticultural grounds.

The new dairy building at the New York Cornell station, to cost, with equipment, $685,000, was nearly completed. A new pomology storehouse, to cost $32,000, and a plant-breeding drying house, to cost $10,000, are to be built. An appropriation of $500,000 was made for a new plant industry building. A tract of 46 acres was purchased for the experimental farm. A 30-acre tract was purchased at the Long Island Vegetable Research Farm, and some repairs were made. A greenhouse was erected costing $16,200, and a laboratory was built and equipped.

A new building for the State board of agriculture was built at Raleigh, N. C., in which offices and laboratories are provided for some of the station staff. The new agricultural building at the college was completed and occupied by certain of the station departments. Various improvements in buildings were made at the Mountain, Piedmont, Tobacco, Edgecomb, and Coastal Plain substations.

The new agricultural building at the North Dakota station was completed and occupied.

At the Ohio station, a new printery was built and 3,242 acres of forest land was purchased. An appropriation of $75,000 was made for a new building to be occupied by the departments of chemistry and entomology, and part of the botany department.

At the Oklahoma station a new sweet-potato storage house was built with a view to making the study of storage diseases a prominent feature.

Two modern egg-laying houses, each to accommodate 300 hens, were constructed at the Oregon station. The station was given increased accommodations in the agricultural building. Considerable equipment was added to the main and branch stations.

At the Pennsylvania station a new beef cattle barn valued at $50,000 was completed during the year, and a new tobacco-curing shed was built and equipped.

The South Carolina station library was remodeled. The State legislature appropriated $25,000 and the Federal Department of Agriculture allotted an equal amount for an office building and insectary for boll-weevil control work at Florence. A six-room office and laboratory building was constructed there.

A greenhouse was completed at the Utah station, and equipped with a set of cement soil-temperature control tanks for use of the department of botany.

At the Vermont station a new refrigerating apparatus costing $5,000 was installed.

At the Virginia station a small barn was remodeled and equipped exclusively for investigations at a cost of about $5,000. A 50-acre tract of land was purchased in Pittsylvania County for experimental purposes, and a stable and tobacco barn were built on the place, the land and buildings costing $9,000. A lysimeter equipment of 63 tanks was completed and put in use.

At the Washington station new hog barns were completed. At the Prosser branch station a two-story house for the farm help and a dairy barn were built. A laboratory for the study of cranberry diseases was established at Sevier.

A new dairy barn was completed at the West Virginia station at a cost of $30,000. A residence was built at the animal husbandry farm at a cost of approximately $6,500.

At the Wisconsin station a section of the greenhouse for plant disease investigations was nearly completed and equipped. The land, 95 acres, heretofore leased for the Hancock branch station, was purchased. New buildings and equipment were provided at the Ashland branch station.

At the Wyoming station a new parasitology and veterinary building, costing about $14,000, and a new poultry building, costing about $12,500, were completed and partially equipped during the year. Various farm buildings and structures were improved and much needed drainage was undertaken. Additional equipment was provided by a special State fund of $3,200 for the horse breeding experiments, in cooperation with the United States Department of Agriculture. A central sewerage system for the buildings on the animal husbandry farm was installed.

REVENUES OF THE STATIONS

The total income of the stations for the year from all sources, excluding the Federal insular stations, was $9,283,653.20. Of this amount, $1,440,000 was from Federal appropriations under the Hatch and Adams Acts, leaving $7,843,653.20 from sources within the State, which included $5,539,077.02 from State appropriations, $373,977 from fees, $1,050,238.55 from sales, $112,415.12 from miscellaneous sources, and $767,945.51 carried over as a balance from the previous year. This is an increase in station resources over last year, exclusive of Federal funds, of $1,368,248.83.

Twenty-seven stations received an increase in State appropriations over the previous year, 14 received a decreased appropriation, and in 9 there was no change in amount. Nine stations received over $200,000, as follows: California station, $558,996.60; New York Cornell, $404,719.12; Minnesota, $356,746.48; Illinois, $334,666.68; Wisconsin, $252,783.69; Ohio, $252,015; Iowa, $250,000; Indiana, $238,991.38; and New York State station, $211,950.55. Ten stations received from $100,000 to $200,000, 13 from $50,000 to $100,000, 4 from $25,000 to $50,000, 8 from $10,000 to $25,000, 5 less than $10,000, and 1 received no State aid. Complete details of the station receipts and expenditures will be found in the tables at the end of the report.

Appropriations for the Alabama station included $7,500 for the work at Auburn and $27,000 for local experiments. Sales and other sources of income amounted to about $6,000.

The Arizona station received a total of $88,171, being an increase for the year of about $21,640.

Appropriations for the Arkansas station were practically the same as for the previous year.

In California the State appropriation for the station at Berkeley was $157,258 and for the substations $401,738.

The State appropriations for the Colorado station totaled about $125,373. The State mill levy for the year amounted to $99,075 for the station. The legislature appropriated $2,000 a year for two years for experiments at Cheyenne Wells.

The Connecticut State station received an appropriation of $10,000 for a new department of soils. The Storrs station received $17,500 for maintenance and $2,000 as a special sheep fund. An appropriation of $14,600 was received for a new dairy barn.

The State support for the Delaware station was $20,000 for the year.

The Florida Legislature made an annual appropriation of $55,000 to the station to carry on work throughout the State, and including special appropriations of $7,500 for pecan investigations, $10,000 for citrus investigations, $13,500 for the tobacco experiment station, and $20,000 for the Everglades station.

The State fund for the Georgia station was $6,813.35.

The Idaho station received an increase from the State of nearly $7,500, giving a total of $17,458.

In Illinois there was an increase in appropriations of nearly $25,000 for the station.

There was an increase in State support of about $24,000 for the Indiana station. The canners' association gave $2,200 for tomato studies.

There was no change in the State appropriation of $250,000 for the Iowa station for the year.

The Kansas station received an allotment of $40,000, plus the salaries of the station staff, totaling nearly $95,000, and representing a decrease of $2,000 as compared with the preceding year.

There was no change in the State appropriation for the Kentucky station, which remained at $50,000.

The Louisiana Legislature has changed its former policy of making specific appropriations to the different branch stations, and now makes a single appropriation for all experimental work. This amounted to $56,637 for the year.

Special appropriations of $5,000 each were made by the Maine Legislature for the Highmoor and Aroostook farms and for animal husbandry investigations, and $10,000 was appropriated annually for two years for general maintenance.

The Maryland station received $54,629 for the central station and $6,943 for the Ridgely substation.

There was a small increase in State funds for the Massachusetts station, which amounted to $107,410 for the year.

The total amount expended for research at the main and branch stations in Michigan from all sources, including the soil survey, was $245,810, of which the substations received $38,780, and the soil survey $10,000.

The Minnesota State appropriations for the main station were about $268,000, and for the substations about $88,700. The Association of Eastern Paint and Oil Dealers gave $1,000 for investigations in growing wheat and flax together, and a local milling company donated $2,000 for a cereal-breeding greenhouse. A fellowship was established by a commercial concern for investigations in the cracker industry and there were special State appropriations for investigations in drainage and sirup making from sweet-corn stalks.

The total State receipts of the Mississippi station were $82,600, of which $15,300 was for the McNeill branch station, $17,000 for the Holly Springs branch station, and $10,000 for the Raymond branch station.

The Missouri station received $36,024 from the State, the total income from all sources, including balances, being $118,456.

The State appropriation for the Montana station was $134,485, being practically the same as for the previous year. The allotment for the central station was $82,845, and for the substations $51,640.

The Nebraska station had State aid amounting to $178,780.

The Nevada station had no increase, the State appropriations being $1,000 per year.

The New Hampshire station received $7,000 from the State, this being an increase of $2,000 over the previous year.

The total State funds for the New Jersey stations were $155,817.

The New Mexico station State appropriation was $7,500, the same as for the previous year.

The total allotments for research at the New York Cornell station amounted to $404,719. The income of the State station was $211,950.

The North Carolina station does not have any direct State support, but it had an allotment of about $188,346 from the State board of agriculture, which includes the support for the branch stations.

The North Dakota station received only $9,593 from the State, but had a balance of $175,691. The total from all sources was $293,232. The legislature failed to appropriate for the soil survey and the appropriation for the demonstration farms was reduced. The paint and varnish manufacturers gave $4,000 for work with flax.

The State appropriation for the Ohio station was $252,015, which has been more than doubled for the next biennium.

The Oklahoma station again had a State appropriation of $10,500, in addition to which $4,000 was appropriated for an experimental feeding shed for beef cattle, $2,500 for a potato and fruit storage house, $1,600 for machine sheds, and $5,000 for poultry houses.

The total revenue of the Oregon station was $203,689, of which $92,000 was from State appropriation.

The Pennsylvania station had a total income of $84,325, the State support being $27,584. There was a special appropriation for the biennium of $6,000 for tobacco investigations. In addition, $3,197 was provided for raisin investigations and $1,152 for yeast studies. About $6,500 of the Adams fund was allotted to the Institute of Animal Nutrition.

The resources of the Rhode Island station, aside from the Federal funds, were $10,325 from the State and a sales fund of $5,582. The State appropriation included $6,300 for an economist on the station staff.

For the year ended December 31, 1923, the South Carolina Legislature appropriated $50,000 for agricultural research, $10,000 for regulatory activities, and $25,000 for boll-weevil control. Sales and other income amounted to about $24,000. The Pee Dee and Coast substations received $50,000.

The State appropriation for the South Dakota station for the year was $14,420. The four substations received $3,250 each.

The State support for the Tennessee station was increased more than $20,000 over the previous year, being $53,973. An appropriation of $5,000 was made for a new greenhouse.

The Texas station received a total income of $305,118, of which $197,985 was from State appropriation, the balance being from Federal and other sources.

The Utah station had an income of $49,662 from the State, making a total income from all sources of $86,650.

The only State income received by the Vermont station was that allotted

for inspection work and expended for that purpose, amounting to $4,150.

State appropriations for the Virginia station amounted to $57,860.

At the Washington station a full millage tax for the support of the institution as a whole was granted by the legislature and a slight increase over the previous year for the support of the main station, which amounted to $105,276, was granted by the board of regents. In addition a special biennial appropriation of $34,000 was made for the irrigation station at Prosser, as well as an appropriation of $9,000 for cranberry investigations.

The West Virginia station received $120,000 from the State, this being the same amount received the previous year.

Expenditures from State funds for research work during the year at the Wisconsin station amounted to $252,783, as compared with $215,000 for the previous year.

The Wyoming station received $12,000 from the State. The University of Wyoming receives 9 per cent of oil royalties on Government lands, amounting to several hundred thousand dollars annually. The station is benefited by the use of these funds not only in the way of improved bu ldings and equipment for work, but through the fact that the university is able to carry a large proportion of the overhead expenses formerly paid out of station funds.

CHANGES IN PERSONNEL

There were four changes in directorship of the stations during the fiscal year 1923. E. H. Jenkins resigned as director of both the college and State stations in Connecticut, and was succeeded by W. L. Slate, jr. At the New York Cornell station, A. R. Mann relinquished the duties of director, R. W. Thatcher succeeding to the directorship in addition to that of the New York State station. C. T. Dowell resigned as director of the Oklahoma station and was succeeded by M. A. Beeson. At the Wyoming station, A. D. Faville resigned as director and was succeeded by J. A. Hill.

At the Alabama station, L. E. Miles succeeded A. H. W. Povah as associate plant pathologist.

J. J. Thornber, director of the Arizona station, assumed also the duties of dean of the college of agriculture, succeeding D. W. Working. G. E. Thompson, agronomist, resigned and was succeeded by R. S. Hawkins as acting agronomist. R. H. Williams resigned as head of the animal husbandry department and was succeeded by E. B. Stanley as acting head.

V. H. Young was appointed head of the department of plant pathology at the Arkansas station to fill the vacancy caused by the death of J. A. Elliott.

There were a number of changes at the California station. A. W. Sampson was placed in charge of a new department of range management. F. W. Woll, of the animal nutrition department, died. W. H. Chandler was appointed pomologist, and H. E. Erdman and S. W. Shear as associates in rural institutions. A. E. de Fremery, associate in farm management, and I. F. Torrey, associate in chemistry, resigned. The following appointments were made at Davis: C. H. Bisson, chemist; H. A. Jones, associate in olericulture; W. M. Regan, associate in animal husbandry; W. W. Robbins, associate in botany; and J. L. Stahl, associate in pomology.

M. F. Morgan was appointed specialist in soils at the Connecticut State station. G. H. Chapman, research director of the tobacco station at Windsor, resigned, and was succeeded by C. M. Slagg. S. T. Sealy resigned as deputy in charge of mosquito elimination and was succeeded by R. C. Botsford.

At the Idaho station M. R. Lewis succeeded T. C. Mead as associate in agricultural engineering.

The changes at the Illinois station included the appointment of V. W. Kelley as associate in pomology and the resignation of the following: J. A. Detlefsen, chief in genetics; F. F. Elliott and W. J. Roth, associates in farm management; J. H. Hedgcock, associate in farm mechanics; J. B. Rice, associate in swine husbandry; and H. A. Ross, associate in dairy husbandry.

L. C. Kigin resigned as associate in veterinary science and R. H. Carr as associate in animal nutrition at the Indiana station.

A number of changes were reported from the Iowa station. S. A. Beach, head of the department of horticulture, died. C. L. Holmes succeeded E. G. Nourse as chief of the department of agricultural economics and P. L. Miller was added to the department as assistant chief. E. W. Lindstrom was appointed head of the new department of genetics. W. H. Stevenson, head of the department of farm crops and soils, returned from a year's leave with the International Institute of Agriculture at Rome. C. J. Drake was appointed head of the department of entomology. J. M.

Shaw was appointed assistant chief in dairy husbandry, succeeding J. Waddell; R. L. Parker, assistant chief in apiculture, succeeding O. W. Park; and W. C. Calvert, assistant chief in truck crops, succeeding A. W. Rudnick. F. H. Culley, chief in landscape architecture, resigned.

At the Kansas station C. O. Swanson succeeded L. A. Fitz as head of the department of milling industry. A. M. Paterson and H. B. Winchester, associates in the department of animal husbandry, resigned, as did R. L. Hensel, associate in pasture management.

Changes at the Massachusetts station included the appointment of G. E. Gage as head of the department of veterinary science to succeed J. B. Paige, deceased. F. A. Hays was appointed research professor of poultry husbandry. J. L. Bailey succeeded A. P. French as investigator in pomology.

At the Michigan station V. R. Gardner was appointed head of the department of horticulture to succeed C. P. Halligan, who was transferred to the head of the department of landscape gardening. F. C. Bradford and G. E. Starr were appointed associates in horticulture.

H. W. Vaughan was appointed in charge of beef-cattle husbandry at the Minnesota station.

E. Barnett, head of the department of animal husbandry at the Mississippi station, was transferred to the teaching staff and was succeeded as head of the department by G. S. Templeton. C. J. Goodell was appointed assistant agricultural economist. R. W. Lobdell, zoologist, was put wholly on station time.

At the Missouri station V. R. Gardner resigned as head of the department of horticulture and was succeeded by T. J. Talbert. A. G. Hogan succeeded C. R. Moulton as head of the department of agricultural chemistry.

Changes at the Montana station included the resignation of W. F. Schoppe as head of the department of poultry husbandry.

At the New Jersey stations, W. M. Regan, dairy husbandman; M. T. Cook, plant pathologist; and F. App, agronomist, resigned. J. W. Bartlett was appointed dairy husbandman.

J. C. Overpeck was appointed head of the agronomy department at the New Mexico station, and A. L. Walker succeeded J. H. Bardsley as poultryman.

The principal changes at the New York Cornell station, in addition to the change in directorship, already noted, were the appointment of A. J. Heinicke as head of the department of pomology to succeed W. H. Chandler, and the resignation of O. B. Kent from the department of poultry husbandry.

At the New York State station H. B. Tukey was appointed associate in horticulture, F. H. Lathrop associate in entomology, and E. V. Shear associate in plant pathology, for research work in the Hudson River Valley.

R. Schmidt was appointed vegetable specialist at the North Carolina station to fill the vacancy caused by the death of L. H. Nelson, and V. W. Lewis was appointed specialist in livestock marketing.

At the North Dakota station A. H. Benton was appointed head of the department of marketing and rural finance.

The more important changes at the Ohio station included the resignation of A. D. Selby, chief of the department of botany, who was succeeded by H. C. Young.

W. A. Craft was placed in charge of the breeding work, in the department of animal industry, and F. B. Cross was appointed associate in horticulture, at the Oklahoma station.

D. C. Mote succeeded F. H. Lathrop as associate entomologist at the Oregon station. R. E. Stephenson was appointed associate soils specialist. J. Dryden, chief in poultry husbandry, resigned.

Changes at the Pennsylvania station included the resignation of C. A. Hunter, of the department of bacteriology. E. B. Forbes assumed the directorship of the Institute of Animal Nutrition.

At the Rhode Island station B. L. Hartwell, the director of the station, relinquished the position as chemist and P. S. Burgess was appointed head of the department. P. H. Wessels resigned as associate chemist. F. R. Pember, associate in glasshouse experiments, was granted an extended leave of absence.

Among the changes at the South Dakota station were the resignations of T. H. Wright, jr., associate in dairy husbandry, and A. T. Evans, associate in agronomy.

Appointments at the Virginia station included W. D. Saunders, dairy specialist; C. E. Seitz, head of the agricultural engineering department; T. K. Wolfe, agronomist; S. A. Wingard, associate in plant pathology; and J. J. Vernon, associate agricultural economist.

At the Washington station P. W. Allen succeeded W. I. Nightingale as bacteriologist.

The resignation of A. G. Johnson, associate plant pathologist, is noted at the Wisconsin station.

In addition to the change in directorship at the Wyoming station, already noted, F. S. Hultz succeeded F. A. Hays as head of the department of animal husbandry.

SOME RESULTS OF STATION WORK

SOILS

Acidity.—That the intensity of acidity as determined by the hydrogen-ion concentration bears in general no direct or simple relation to the quantity of acid present in the soil was indicated by studies at the Maryland station. The intensity of acidity in many instances appears to be of greater significance in biochemical processes than is the quantity of acid present. That acid phosphate does not tend to make the soil acid, as is commonly believed, is shown by results of 25 years' cylinder experiments at the New Jersey stations. Plats that had been limed for this period showed a hydrogen-ion concentration of from pH 6.8 to pH 7 and grew better corn than unlimed plats showing a concentration of pH 5.2. Plats that had received ammonium sulphate had a concentration of pH 4.8, and practically nothing will grow on them. Cultures with water extracts from this soil showed that the trouble lies with the soluble aluminum, for if this is corrected crops will grow. Basic slag, lime, or acid phosphate was found to correct this condition by precipitating the aluminum. The condition is also largely corrected by the addition of manure, after which corn makes a fair growth, even with a pH value of 5.1.

The Michigan station has observed that the natural weathering of soils leaves them in layers or horizons of varying acidity. The second layer, just beneath the surface, is much more acid than the surface, but this depends upon the climate, drainage, and vegetation. The third layer is one of concentration, the reaction depending on conditions, whereas the second layer is one of leaching. Even in limestone soils the second layer may be acid.

The colloidal clay of an acid soil, according to the Missouri station, appears to be a true acid, which when neutralized gives a characteristic end point, forming a colloidal salt when the concentration of the hydroxyl ions becomes sufficiently great.

Soils high in organic matter did not respond to liming as much as equally acid soils low in organic matter in experiments at the Indiana station.

In experiments at the Wisconsin station seeds germinated at acidities too strong for seedling plants, and the latter were more sensitive to acids than older plants. Alfalfa and clover made maximum growth and produced most nodules at a hydrogen-ion concentration of pH 7 and pH 8—that is, near neutrality. Alsike and red clover grew better with an acid reaction of pH 5 to pH 6 than did alfalfa, and alsike clover withstood an alkaline reaction better than alfalfa. Oats made a maximum growth at about pH 6 and wheat at pH 6 to 7. After 75 days in soils of different degrees of acidity, alfalfa nodule bacteria were dead in a pH 5 concentration, red clover bacteria with pH 4.5 to 4.7, and soybean bacteria with pH 3.5 to 3.9. The texture of the soil exerted no appreciable influence. The results indicate the necessity of frequent inoculation and liming of acid soils.

The acidity of muck soils was found by the North Carolina station to be due, to some extent at least, to the oxidation of the nitrogenous organic matter. The failure of heavy applications of lime to neutralize all of the acidity can be ascribed to the acceleration of this oxidation process by the lime applied.

The Arkansas station found that on acid soils treated with finely ground rock phosphate, oats were relatively richer in phosphoric acid than those grown on neutral soil. Applications of lime reduced the amount of phosphoric acid which the plant obtained from the soil.

Alkali.—Leaching experiments at the Utah station showed that soil containing sodium carbonate leaches very slowly and, after leaching, is in a bad state of tilth. Those containing sodium chloride leached more readily but were also left in a bad state of tilth, while those containing sodium sulfate leached rapidly and the soil was left in a fair state of tilth. The solubility of lime was increased by the presence of alkali in the soil, and the proportion in which calcium and magnesium was rendered soluble in some soils makes it appear probable that at times a toxic calcium-magnesium ratio may occur. Phosphorus, potassium, and nitrogen were leached from the soil in much larger quantities in the presence of alkali salts

than in their absence. The results indicate that the long unproductive period following the drainage of alkali soil is due to two factors, (1) the removal with the alkali salts of much of the readily available plant food, thus requiring a period of further weathering before sufficient plant food is available for crop production, and (2) the poor state of tilth of the drained soil, with possibly, at times, a toxic lime-magnesia ratio.

Adobe soils containing large amounts of alkali become impervious, according to the New Mexico station, when leached with pure water, and hence it is not possible to remove toxic amounts of alkali from such soils by irrigation alone. Sodium chloride is the constituent most readily removed by leaching. Soluble phosphoric acid, when added as a fertilizer, was not leached out by irrigation water, and soluble compounds of potassium and nitrogen were not removed so readily as the common alkali salts but more so than phosphorus.

The California station found that if the water table of the soil was low, 40 feet or more, plants withstood a fairly high degree of alkali in the irrigation water, there being no accumulation of salts at any point, because of the downward movement of the solution. The salts, however, did not move with like rapidity by capillarity. In attempts to reclaim impermeable land, calcium nitrate gave good results, as did sulphuric acid; but nitrate of soda brought about very unfavorable conditions.

In experiments at the Idaho station various combinations of sodium chloride, carbonate, and sulfate, and especially the carbonate, showed a certain stimulating effect on the second crop after application of the alkaline salts. Similar stimulation of the ammonifying and nitrifying organisms was also observed, with larger quantities of the carbonate than the crops could tolerate. Treatment of alkali spots, locally known as "slick spots," where the principal trouble is evidently imperviousness to water, showed that sulfuric acid flocculated the colloidal matter and improved the percolation. Sulfur and gypsum also improved it, but somewhat more slowly than the acid. Aluminum sulfate was an effective flocculent.

Land treated for alkali will rapidly go back to its original condition if treatment is discontinued, according to the Arizona station. With a constant percentage of 0.2 of sodium carbonate, it was found that tolerance of the alkali by crops was greater in heavy than in light soils. In tests of neutralizing the alkalinity with various acids there was a favorable effect with barley from tartaric acid, but with wheat this was not in proportion to the quantity added, although there was some improvement. Ferrous sulfate gave a gradual increase in production in proportion to the quantity used, and this was true to some extent with gypsum. Acetic acid gave some benefit, but not in proportion to the quantity used and not to the same extent as with tartaric acid. The use of free sulfur doubled the yield of wheat, and iron pyrites gave a slight increase in yield.

In experiments at the New Jersey stations sulfur was found to have a marked influence on the permeability of alkali soils. Water readily passed through a soil treated with sulfur, but very little went through the untreated soil, even after prolonged contact. Sulfur-treated soils permitted a rapid capillary rise of water.

Nitrogen.—The New York Cornell station found a rapid disappearance of nitrates from the soil under a growth of timothy. Applications of as much as 900 pounds of nitrate per acre disappeared rapidly. The nitrogen contained in the grass did not account for the disappearance, and evidence obtained from lysimeters indicated that the loss was not due to leaching or to removal from the soil by denitrification. It is believed the nitrate was utilized by various organisms of the soil and was transformed into ammonia or some organic combination. There was a large loss of both nitrogen and lime from bare soil, but the loss of nitrogen in the drainage water from grasslands was negligible. The loss of nitrogen from soils under different fertilizer treatments varied considerably with the type of soil and the form of nitrogen present. Carbonaceous material was also responsible for reduction in nitrates. Timothy was found to reduce nitrates and corn to favor their production. During the later period of crop growth nitrate production decreased.

The presence of nitrates in the soil decreased its nitrogen-fixing power in experiments at the Utah station. Applications of 5 and 15 tons of manure per acre for an 11-year period materially increased the nitrogen-fixing power of the soil, but the increase per ton of manure was greatest with 5 tons. Five-ton applications yearly

for 11 years increased the nitrogen content of the soil by 1,370 pounds, which was 486 pounds more than the nitrogen applied. The application of 15 tons increased the nitrogen content in the first 3 feet 2,248 pounds, which was 450 pounds less than the nitrogen applied. The percentage distribution of the total nitrogen in the first, second, and third foot was respectively 41, 33, and 26.

Lysimeter studies at the New York State station showed that, when large amounts of dried blood were added to a soil growing alfalfa, the plant utilized the nitrogen from this source instead of that assimilated from the air. After five years six times as much nitrate leached out from the legume lysimeters as from the nonlegume. Legumes maintained a much higher nitrogen plane than did nonlegumes.

That sodium nitrate decomposes rapidly in acid soils, more slowly in neutral soils, and still more slowly in alkaline soils was shown by studies at the Oregon station. Sodium nitrate was found by the Massachusetts station to conserve lime in the soil, less escaping in the drainage water when it was applied.

A study of nitrate production at the Missouri station showed that the crop is of significant influence in removing nitrates from the soil and their accumulation is almost reciprocal to the rate and season of crop growth. Early spring tillage, especially plowing, increased nitrate accumulation, but surface tillage lessened it. A straw mulch had a decided effect in holding down nitrate accumulation. Lime was important as a means of increasing nitrate accumulation, whether the soil had been manured or not, but the addition of new organic matter was essential to increase the nitrates, and manured soil accumulated more than unmanured soil. Lime was an outstanding means of increasing nitrification on all crops and for all fertilizer treatments.

Studies with onions, sugar beets, cantaloupes, and corn at the Colorado station showed that nitrates developed rapidly under clean cultivation up to 70 to 100 parts per million in the soil. With barley and clovers, nitrate formation did not exceed 10 or 12 parts per million. Nitrates reached a maximum about July.

On impervious Kirkland upland subsoil the Oklahoma station found that manure with either the oxid or carbonate of lime increased both ammonification and nitrification, manure being less effective in this respect than lime. Nitrification was, at a maximum in July and lowest in August, the moisture content of the soil also being lowest in the latter month. Manure gave a little more increase in ammonification than in nitrification and increased the penetration more than lime. It also tended to increase the moisture of the soil, especially in the first 2 or 3 feet.

A depression of nitrification by the long-continued growing of one crop, which rotation relieved somewhat, is reported by the Missouri station. Applications of lime resulted in a decided increase in nitrification, and straw mulch checked nitrate accumulation.

Lime and to a less extent phosphorus favored nitrification in experiments at the Montana station. Sulfur in the form of sulfate stimulated nitrification in certain soils. There appeared to be a correlation between the amount of lime and sulfur necessary in a soil to increase crop production and that necessary to increase nitrification. In greenhouse tests at the Oregon station, liming resulted in increased bacterial activity, including ammonification, nitrification, and nitrogen fixation.

A close correlation was found by the New Jersey stations between soil fertility and the number of bacteria concerned in nitrogen availability and in the reduction and oxidation of carbon compounds. Nitrification was a good index of this, but ammonia fixation was not. In the second year after lime was applied there was a close correlation between crop yield, number of bacteria, and amount of nitrification.

That nitrifying organisms can withstand large quantities of alkali was shown in investigations at the California station, but strains differ in this respect. Nitrogen-fixing organisms did not function well except in a slightly acid medium.

The Utah station found that more water is required for optimum bacterial activity in alkali soil than in those free from excess of alkali. In very dilute solutions, nitrates in the soil solution stimulated nitrogen fixation, but in larger quantities retarded it. Likewise very small quantities of dried blood accelerated the action, but larger quantities (2 per cent) inhibited fixation. Barnyard manure up to 15 tons per acre accelerated fixation. The presence of arsenites in soil, as may result from spraying, was found to reduce the action of beneficial bacteria, such as ammonifiers.

Increasing the pH value of an alkali soil to 6, or lowering that of an acid soil was shown by the Kansas station to make conditions favorable for the growth of Azotobacter. By adding organic acid to a soil, the nitrogen ion concentration was lowered. Acetic acid up to the rate of 45 tons per acre disappeared when added to the soil, the organisms using the acid as a source of food.

Sodium chloride and sulfate reduced ammonification and nitrification in experiments at the Idaho station, but sodium carbonate slightly increased these processes and also showed a slight tendency to overcome the toxicity of the chloride and sulfate.

Organic matter.—The Pennsylvania station found that land kept in permanent sod for 40 years maintained the organic matter of the soil better than a rotation system, even when manure was applied. With continuous cropping manure-treated soils lost 85 per cent of the organic matter applied, but there was more residual organic matter in the soil that had received lime with the manure. The heavier the manure application the greater was the relative loss of applied organic matter. Manured plats had increased in organic matter at the rate of 343 pounds per acre. Nitrate of soda and sulfate of ammonia plats contained less organic matter than those receiving potash and phosphate. Manured plats contained 2,000 pounds per acre more active humus than complete fertilizer plats. There was less residual active humus in the plats receiving land plaster, burnt lime, limestone, nitrogen, or potash than in the check plats. An average of 63 per cent of the total nitrogen applied in manure and 74 per cent of that applied in mineral fertilizers had been lost from the soil. Land plaster plats contained considerably less organic matter than plats treated with burnt lime and limestone. The results, therefore, show no justification for the theory that burnt lime exerts a more destructive action on the organic matter of the soil than other forms.

After 10 years' treatment limed plats at the New York Cornell station contained more organic carbon and nitrogen than unlimed plats. There had been a decrease in organic carbon and nitrogen on the plats in rotation without legumes. Plats kept in grass showed an increase in organic carbon and nitrogen, and plats in rotation with legumes contain more nitrogen than those in rotation without legumes, the increase being greater in the limed than in the unlimed soil. Crops in rotation with legumes removed more nitrogen from the soil than did those without legumes. Plats kept in grass lost less nitrogen in the crops than did the plats in rotation with legumes. The ratio of organic carbon to nitrogen remained fairly constant under various treatments, decreasing or increasing correspondingly.

The Washington station found that straw with a nitrogen content of about 0.5 per cent decomposed at a very uniform rate throughout the growing season and that alfalfa, with a nitrogen content of about 2.5 per cent, decomposed very rapidly during the initial period of about 16 days and then dropped below straw. Thus the soil organic matter accumulates more rapidly with alfalfa than with straw. From the standpoint of crop yield, straw acted detrimentally by inhibiting nitrate accumulation, but alfalfa rapidly increased the nitrate-nitrogen content. The biological activity of soils decreased directly with the loss of organic matter and nitrogen. The nitrogen-carbon ratio in soils tends to become practically constant at about 1:12, irrespective of the source or proportions of these constituents applied. The carbon can not be permanently increased or even maintained unless the necessary nitrogen is provided to maintain the ratio. The nitrogen-carbon ratio in material applied to the soil had a pronounced influence on the kind and rate of decomposition. Thus wheat straw with a wide nitrogen-carbon ratio (1:75) had a depressing effect on nitrate formation when applied to the soil, which persisted until decomposition had proceeded to the point of restoring the proper ratio, whereas legume hay or green manure with a nitrogen-carbon ratio of 1:10 gave an immediate and rapid formation of nitrates. Studies on dry basaltic soils, under a limited rainfall, with a low clay content, showed that while the nitrogen content of the soil increased with precipitation the nitrogen-carbon ratio remained constant, being narrower in the subsoil than in the surface soil. The organic matter of the subsoil was but slightly affected by precipitation. When precipitation exceeded 15 inches there was considerable loss of nitrogen. It is suggested that this loss can be prevented by replacing summer fallow with a rotation containing legumes.

Solubility of soil constituents.—The Iowa station found no relation to exist between total and organic phosphate in the soil or between carbon dioxide

formation and soluble potash, there being various factors which affect the solubility of potash.

Continued treatment with acid phosphate depleted available potash, whereas calcium sulfate and sodium nitrate increased the water-soluble potash, in experiments at the Ohio station. Limed soils showed a higher potash-fixing power than unlimed soils.

In lysimeter studies the Florida station found that soils receiving their nitrogen in organic form, as from manure, lost less nitrogen and other constituents in the drainage water than those receiving nitrogen in mineral form. Applications of ammonium sulfate caused increased losses of lime, potash, and aluminum.

All forms of calcium and magnesium other than sulfates caused a depression rather than an increase in the amount of potash leached from a soil, in experiments at the Tennessee station. Similar results were obtained by the New York Cornell station, which found that lime made potash less soluble, as shown by the drainage water.

Soils normally showing no water-soluble potash contained soluble potash after treatment with sulfur at rates of 500 to 1,000 pounds per acre, in experiments at the Kentucky station. In only one case was it present after treatment with gypsum.

The Illinois station observed that when rock phosphate and acid phosphate were added to soil they quickly became relatively insoluble, the reaction being practically completed in 24 hours, after which there was no significant difference in the amount extracted from the two carriers. Soils varied widely in their ability to absorb phosphorus from applied phosphates and in the effect of different chemical compounds upon the amount of phosphorus which could be extracted. Double phosphates of iron and alumina and possibly silica were the compounds concerned in the fixation process. With a soil composed wholly of silica, recovery of phosphorus was 60 per cent or more if iron or aluminum was added alone, but if both were added together recovery fell to 30 per cent.

Sulfur.—Soils high in organic matter were found by the Illinois station to contain more sulfur than those low in this constituent. Determinations of sulfur in the rainfall showed that from 30 to 50 pounds per acre are added from this source during the season, which is in excess of that removed by the crop. The Tennessee station found that the outgo of sulfates was increased by the addition of any form of lime and magnesium, except freshly burnt lime, the outgo being decreased with increased applications of the latter. Where excessive quantities of lime were added, the amount of sulfates recovered was less than that brought down by rainfall.

Colloids.—The colloidal swelling of soils was tested by the Arizona station by drying the sample, compressing at 30,000 pounds, adding water or a salt solution, and measuring the expansion. Swelling was accelerated by soluble mineral salts. The temperature of the water affected the rate of swelling, heat accelerating it. Salt or any electrolyte except sulphates also accelerated swelling. Each soil type tested showed a rather characteristic swelling curve at a constant temperature. With the same soil, increasing the viscosity by adding gelatin increased the swelling up to 1 per cent and then retarded it, and adding an electrolyte to the gelatin restored the normal. Apparently the swelling was not due to the viscosity, but the gelatin had a specific effect upon the colloids. This effect is, however, not constant in different soils, suggesting the presence of different colloids.

FERTILIZERS

Standard fertilizers.—Through the efforts of the Texas station, an agreement has been reached among agronomists, chemists, and fertilizer manufacturers on 11 standard fertilizer formulas of high grade for Texas, Louisiana, Arkansas, and possibly Oklahoma. This is in line with similar agreements which have been reached in many of the other fertilizer-using States.

Phosphates.—At the Pennsylvania station, acid phosphate when used without manure was much more effective than rock phosphate, but used with manure the difference was less marked. Sulfur applied with rock phosphate increased its availability.

In experiments extending over 10 years, rock phosphate has shown little effect in the early years of its use at the Virginia station, but is beginning to give very good results which are accentuated by liming.

Ordinary ground rock phosphate, 25 per cent of which is of the fineness of clay, was 49 per cent as effective as acid phosphate, in experiments at the Indiana station. When the phosphate was reground so that 75 per cent of it was as fine as clay, it was 56 per cent as effective as acid phosphate.

Lime.—A comparison of magnesium and nonmagnesium limestone, at the New Jersey stations, showed a slight difference in favor of the former and some evidence that this form favors nitrogen fixation more than nonmagnesium limestone. The results indicated that it is not necessary to fully satisfy the lime requirements of a soil to get good results with most farm crops.

The Rhode Island station has found that with sufficient phosphoric acid there is a marked reduction in the needs for lime.

Gypsum applied as top dressing on new seedings showed no beneficial effects in case of clover or other crops at the Wisconsin station, but at the Oregon station it was found to be especially effective in securing a stand of clover.

Sulfur.—At the Washington sation applications of sulfur on alfalfa at first increased the yield, but this was not maintained without renewed applications. Sulfur applications increased the nitrogen content of the first cutting of clover and alfalfa, but not of the second and third cuttings. The sulfur content of the first cutting of alfalfa was increased, but there was little effect on the percentage of total ash or of calcium. The effects of sulfur varied with different soils, crops, and forms of sulfur. Certain soils showed comparatively little effect of such applications on the soil processes. Additions of organic matter, such as manure, apparently had less effect than did moisture on the behavior of sulfur.

At the Oregon station legumes, particularly alfalfa and red and alsike clover, gave marked response to sulfur fertilizers, which were found to increase the protein content of the crops. Elemental commercial ground sulfur was found to be the most economical form to use, and applications of 100 pounds per acre per year have given marked increase in the yield of crops.

The use of 500 pounds of sulfur per acre on sugar beets, in experiments at the Colorado station, gave an increase in sugar content of 0.5 per cent and increased both purity and tonnage.

At the Idaho station there was greater response to sulfur and less to phosphoric acid in arid than in humid soils. Sulfur increased the nitrogen content of alfalfa, and gypsum increased the yield on Palouse soil.

The use of sulfur slightly decreased the yield of cotton, in experiments at the Texas station, but had no appreciable influence on the development and control of root rot of cotton.

Manure.—Acid phosphate used at the rate of 5 per cent proved to be an efficient preservative of nitrogen in manure, in tests at the New York State station, by inhibiting the organisms that break down the manure. The effect of fresh straw was very detrimental, possibly due to a toxin.

In experiments at the Missouri station manure in a flat pile 6 inches deep lost 39.5 per cent of nitrogen during five months' exposure, from April to September. The loss in a conical pile was 26.55 per cent during the same period. Most of the loss was in a gaseous form.

BACTERIOLOGY

Azotobacter was shown by the Ohio station to grow in an atmosphere of hydrogen, if supplied with nitrogen, showing that the organism is not necessarily an air-nitrogen fixer. In the soil it apparently can not compete with other forms in the utilization of soil nitrogen. It can stand anaerobic conditions and can continue active in an atmosphere of hydrogen and oxygen with no nitrogen. It was found that the dry Azotobacter cell contains about 3 per cent of nitrogen.

A sulfur-oxidizing organism, *Thiobacillus thiooxidans*, was isolated and grown in pure cultures at the New Jersey stations. It gets its carbon dioxide from the atmosphere, being incapable of deriving carbon from carbonates or organic matter, but derives its energy from the oxidation of sulfur. It does not occur in soils to which no sulfur has been added. It is much more active than Beyerinck's organism *T. thioparus*, producing 3 to 4 per cent of acidity in sulfur and standing an acidity of pH 0.58.

Bacillus botulinus was found by the Colorado station in 18 widely distributed soils. Cultures of the organism from canned corn withstood three hours' boiling.

Several bacteriophags were isolated by the Massachusetts station from bacillary white diarrhea, but all were weak. Their real nature, whether enzym or ultramicrobe, has not been determined. A protein extracted from an isolated virulent bacteriophag showed phagic action. The phags were found to cause lysis of the pathogenic bacteria.

PLANT PHYSIOLOGY

Nutrition.—At the Wisconsin station, studies on the feeding power of plants showed that this is not due primarily

to the amounts and kinds of acid excreted, but to various factors of external and internal equilibrium in the nutritient solution. Plants with a high capacity for calcium, feed strongly on rock phosphate because soluble phosphate and calcium carbonate are both removed in proper proportion. When only one soluble product is present, as in feldspar, assimilation of potash depends inversely upon the acidity of the plant sap. The more acid the sap, the more readily can the plant, in competition with the acid system of the soil, obtain the calcium and other basic materials needed to regulate the reaction of the plant sap. It was found that nitrates may be stored by the plant until the proper conditions arise for building up into other forms of nitrogen. The presence of nitrates, as such, in a plant did not materially affect the type of growth. Conditions resulting in a decrease of insoluble nitrogen and a still greater proportional decrease in carbohydrates resulted in a relatively high proportion of insoluble nitrogen to carbohydrates, producing a strongly vegetative and unfruitful plant. Conditions favoring the formation of an abundance of insoluble nitrogen and at the same time an abundance of carbohydrates, resulted in a vigorously vegetative and fruitful plant. Conditions resulting in a decrease of available soluble nitrogen without a decrease in carbohydrates caused a very high proportion of carbohydrates to insoluble nitrogen and produced a weakly vegetable and unfruitful plant. In the case of tomatoes, light within the limits of a six-hour day did not markedly limit the building up of nitrates to insoluble forms of nitrogen, provided there was present an available supply of carbohydrates. A large decrease of carbohydrates in the tomato plant, already high in carbohydrates, was apparently coupled with decomposition of insoluble nitrogen. When this decrease was brought about by reduction in time of exposure to light, new growth was produced, even though there was no external supply of nitrates available to the plant.

With tomatoes grown in a fertile soil and transplanted to sand with a nutrient solution in which different elements were omitted, the following results were obtained by the New Hampshire station: With no phosphorus, the plants were feebly vegetative, deep green in color, and nonfruitful. Compared with those grown with a complete nutrient solution, they were higher in total nitrogen, nitrate nitrogen, and chlorophyll content and also higher in free reducing sugars and total carbohydrates. With no nitrogen, the plants were feebly vegetative and nonfruitful but had a pale green color, and compared with complete nutrient solution plants, were lower in total nitrogen, nitrate nitrogen, and chlorophyll content and higher in free reducing sugars and total carbohydrates. With no sulfur, they were only slightly less vegetative and fruitful than those grown in complete solutions and were slightly higher in total nitrogen, free reducing sugars and carbohydrates, but the effect of omitting the sulfur was not marked. A study of the nitrogen distribution showed that those plants grown in the nutrient solution minus phosphorus were much lower in insoluble nitrogen, higher in soluble nitrogen, and slightly higher in lipoid nitrogen. With nutrient solutions containing no nitrogen, the plants were high in total nitrogen and nitrate nitrogen; with no phosphorus, they were low in total nitrogen. Plants grown without phosphorus, although high in total and nitrate nitrogen, were low in synthesized or protein nitrogen, those grown without nitrogen also being low in protein nitrogen. Large applications of available phosphorus increased fruitfulness and hastened maturity with tomatoes.

Studies with the peach, at the Delaware station, showed that the rapidity of starch transformation was much increased by nitrogenous fertilizers.

At the New York Cornell station, it was found to take about two weeks for nutrients to go from the root to the top of a tree. Nitrates seemed to increase the rate of movement. If nutrients were fed to roots on one side of a tree, they stayed on that side, but water was translocated to all parts of the tree. Similar results were obtained at the Maryland station, where fertilizers applied to the roots on one side of a tree were found to be used only by the trunk, limbs, and leaves directly above and were not diffused throughout the tree.

Nitrates penetrate the cell much more rapidly from slightly acid than from slightly alkaline soils, according to experiments at the California station, the indications being that alkalinity is undesirable in a soil solution. The concentration of ions in cell sap was much higher than in the soil solution, the sap being more acid than the soil solution.

Alfalfa grown in solutions containing sodium chloride, at the New Jersey stations, gave higher yields than

plants grown with no sodium chloride, the roots showing a greater relative increase than the tops. The chlorine content of the plant increased with increasing supply of the element, the greater part being in the tops. With plants grown in solutions lacking the essential elements, the most striking injurious effects were observed in plants in solutions lacking lime, potash, and nitrogen, those lacking phosphorus and iron suffering least. It appeared that sodium could fully replace potassium as a plant nutrient up to the blossoming stage. The calcium content of the plant was greatly increased when potassium and nitrogen were lacking and slightly increased in the absence of phosphorus. The amount of magnesium in the plant was increased when sulphur was omitted and where potassium was replaced by sodium, whereas a decrease of 90 per cent occurred in the absence of nitrogen. Considerably less nitrogen was absorbed by the plant in the absence of calcium and potassium, but the elimination of sulfur and iron caused an increase in nitrogen absorption. Plants in solutions in which potassium was replaced by ammonium sulfate contained more nitrogen. When the solutions were aerated there was superior root growth, reflected in accelerated growth of tops during the later stages of development.

Metabolism.—Studies at the Wisconsin station indicated that, in general, climatic effects on plant metabolism are more pronounced than are those of nutrients. Increase of polysaccharids was found to be associated with a decrease of temperature, with red clover and buckwheat.

Evidence that one of the unicellular green algae (*Chlorella* sp.) can synthesize protein in total darkness, when nitrogen is supplied in inorganic combination, was secured by the New York Cornell station.

Respiration showed little effect on the protein percentage in wheat, oats, and barley, in studies at the Minnesota station. The Pennsylvania station found that nitrates decreased from the lower part of the plant upward, but some was found in the leaves and upper parts.

The New York Cornell station found a relatively high catalase activity in leaves from apple trees growing in good soil, from those receiving clean cultivation, or from heavily pruned or nitrogen-fertilized trees in sod. On the other hand, the activity was relatively low in leaves from trees growing in poor, sandy, or noncultivated land, receiving no fertilizer, and from trees that had been ringed or otherwise injured in such a way as to reduce vegetative activity. It is believed that a test of this activity will serve as a rather sensitive indicator of the nutritive condition. A relatively low catalase activity accompanied a nutritive condition in which the proportion of nitrogen to carbohydrates was very low; and the higher the proportion, the greater was the catalase activity.

Enzymic activity in the peach has been studied extensively at the Delaware station. Nitrogen was found to increase the diastatic activity, and this affected the quality of the fruit. With large applications of nitrogen, tannin transformation was slow and there was an accumulation of this substance in the fruit, which thus became bitter. Moderate quantities of nitrogen were found to increase the enzymatic activity in the transformation of amygdalin, but larger quantities did not. Although the yields were better from nitrogenous fertilization, the quality of the fruit suffered. Phosphates were found to increase the amygdalin. Increased nitrogen application did not increase the protein enzymic action and transformation. In studies with corn it was found that high protein was associated with high reducing enzymes, and a high oil content with high diastatic activity. Using this as a basis in inbreeding corn, vigor has been kept up with high protein and oil strains but not with low strains. An increase in vigor did not necessarily mean an increase in yield.

A study of the nature of the hydathode water of plants, at the New York Cornell station, showed it to contain substances similar to that of the plant sap and possibly similar to the secretions from the plant roots. The total solids in hydathode water from the corn plant was 1,030 parts per million. In timothy it was considerably less. These solids were more than half organic. There were indications of the presence of nitrites, nitrates, materials capable of reducing methylene blue, catalases, and peroxidases. It was a good medium for the growth of bacteria. The hydathode water obtained from young plants of corn, timothy, and oats was nearly neutral, but the acidity increased as the plants got older.

Growth.—In studies at the New York Cornell station the top growth of barley and corn was nearly always increased as the supply of nitrogen increased. The absolute root growth, on

the other hand, was usually decreased with high nitrate concentration in the nutrient solution. With medium nitrate concentration the total growth was sometimes greater and sometimes less than with low concentration. The ratio of top to root always increased as the nitrate concentration increased, often resulting with corn and barley, in actually smaller roots. Flax showed no consistent response to changes in nitrate concentration. As the corn and barley plants grew older, the smaller were the roots relative to the tops. Nitrates did not, however, directly decrease root growth. With a low water content of the soil, longer roots were produced; and nitrates produced smaller roots in relation to the top growth unless the tops were removed, in which case the roots were stunted.

Potatoes showed an increase in dry weight of tops with each increase in soil moisture, with both high and low fertilizer treatment, in experiments at the New Jersey stations; but less water was required to produce a gain of dry tops in the high fertilizer series than in the low. Maximum yields of tubers were produced with a medium moisture content. The differences in yield between cultures of different moisture content were greater than between cultures of the same moisture content but with different fertilizer treatment.

Transpiration and leaf temperature.—An investigation of the effect of transpiration on temperature, at the New York Cornell station, showed that this does not cool the leaf much and does not have an effect in regulating the temperature. At the Kansas station, observations taken between 9 a. m. and 4 p. m., on wilted leaves of corn, sorghum, soy beans, and cowpeas showed the temperature to be respectively 1.85°, 1.55°, 2.8°, and 4.65° C. higher than the temperature of turgid leaves of these plants under the same conditions, with the exception of the moisture content of the soil. The percentage of available water in the soil, above the wilting coefficient, was from 2 to 4 per cent for the wilted plants and from 10 to 12 per cent for the turgid plants. The ratio of the rate of transpiration of the turgid leaves to that of the wilted leaves was 2.4 to 1 in the case of corn and sorghum and 3.5 to 1 in the case of cowpeas and soybeans. The temperature of the leaves during the night was approximately that of the air. During the hours of early morning and evening and during the day when weather conditions were comparatively mild, the temperature of a turgid leaf was slightly lower than that of the air. In direct sunlight, the temperature of the turgid leaves fluctuated slightly above or below air temperature, but the average temperature of the leaves was approximately that of the air. The temperature of the base of the leaves in direct sunlight was always lower than that of the tip region, varying from 1° to 1.5° C. depending upon the nature of the leaf and the available water supply. The temperature of sprayed leaves of potatoes was lower than unsprayed leaves.

Effect of light.—At the Massachusetts station a reduction of 15 per cent of light gave a marked increase in vegetative growth. A 20 per cent shading delayed maturity of the potato. Studies on ultra-violet light in the greenhouse indicated that it produces a kind of coagulation. When the short light waves were cut out by suitable glasses there was greater growth of the plant and their presence produced a more compact habit of growth. Insects were found to be able to distinguish ultra-violet light and will go to it. Red light produced most photosynthesis, and the use of red light in the night increased growth perceptibly.

In investigations at the New Hampshire station with an abundant supply of moisture and nitrogen, with a short day, plants were light green, nonfruitful, low in carbohydrates, and high in total and nitrate nitrogen. With a long day they were green in color but unfruitful, low in carbohydrates, and high in total and nitrate nitrogen. With available nitrogen restricted in proportion to daylight, they were green, fruitful, and medium in carbohydrates and in total and nitrate nitrogen, and with much restricted nitrogen and full daylight they were yellowish green in color, unfruitful, high in carbohydrates, and low in total nitrogen, with an abundance of nitrate nitrogen. Shading apple trees reduced fruit-bud formation to almost zero, while unshaded trees gave about 65 per cent of fruit-bud formation. The shaded trees were higher in moisture and total nitrogen and lower in dry matter, free reducing sugars, and starch. Shading appeared to be effective either by reducing carbon elimination or by increasing nitrogen intake or both. Ringing, on the other hand, greatly increased fruit-bud formation, apparently by preventing translocation of the carbohydrates to the roots. Shaded trees were much lower in carbohydrates, but were not

lower and were perhaps even higher, in insoluble nitrogen. Shading did not affect protein synthesis.

Sunlight gave a high nitrogen–low carbon ratio, in experiments at the Ohio station. With a number of plants light increased the leaf surface but not the root system, and the leaves were thinner.

When too little light was supplied, the Michigan station found that wheat plants were abnormally tall. With increased light they were normal, but the same combination of salts (in triangle tests) was not the optimum for both conditions, showing that light is a factor in the utilization of nutrients. Too strong light killed the plants.

Effect of manganese, iron, and aluminum.—In experiments at the Kentucky station with a number of kinds of plants grown with and without manganese, all plants from which this was withheld showed conspicuous signs of the need of this element, as indicated by stunted growth, lack of chlorophyll, and dying back of the young shoots, and finally of the whole plant, without fructification. It seemed to be a necessary element for the growth of the plants. In cereal seeds tested the manganese content was equal to the iron content, but in legume seeds it was less. In addition to manganese, copper and zinc in minute quantities were also shown to be necessary for plant growth. All three of these elements were found in the germ of corn, but little or no copper in the endosperm. A little more copper and zinc were found in yellow than in white corn germs.

At the New Jersey stations, quantitative determinations of iron in the plant as a whole showed that a concentration of iron in the nutrient solution in excess of that required to maintain the plant may result in iron toxicity, but the leaves may sometimes become chlorotic from an insufficient supply of iron, with an abundance in the stems and petioles. A concentration in the nutrient solution not above the maximum required to maintain the plant, tended toward an equal distribution throughout the plant. There appeared to be a delicate balance within the plant in regard to this element, which requires that the available iron in the culture medium be limited to very narrow ranges of concentration. Soluble ferric phosphate in low concentrations was toxic to soybeans in solutions containing ammonium sulphate, but ferric glycero-phosphate in the same concentrations, owing to lower solubility, produced excellent plants. The amount of iron required to maintain plants in a healthy condition, when supplied by the latter compound, became very toxic when supplied by the former. A direct correlation was found between the decrease in hydrogen-ion concentration of the culture solution and the appearance of chlorosis in the plant. With soluble aluminum salts, including the nitrate, chloride, and sulfate, low concentrations had little if any effect on the growth of tops of wheat seedlings, but all concentrations were injurious to the growth of the roots, and a progressive decrease in tops and roots took place with increasing concentrations. The toxic effect was the result of the aluminum ion and not the increased hydrogen-ion concentration resulting from hydrolysis.

In a study of the relation of metallic ions to disease, at the Indiana station, corn plants in soil pot cultures were much less affected by innoculations of *Gibberella saubinetii* when aluminum phosphate, ferric phosphate, and manganese phosphate were added than when aluminum sulfate, iron sulfate, and sulfuric acid were added, showing an important relation between the phosphate and metallic ions, in so far as their absorption and use by the plant is concerned.

Seed studies.—The New Jersey stations found that seeds of high medium weight produced better plants than lighter or abnormally heavy seeds. Germination in general took place more rapidly in light than in heavy seeds. In the Lima bean, the average air-dry weight of beans produced was about 44 per cent of the air-dry weight of the tops, hence the average large plants produce a correspondingly greater crop weight. In corn, the air-dry weight of stalk and husk increased with the increase in weight of seed from which the plant was grown.

Some seeds withstood a pressure of 40,000 pounds to the square inch, alfalfa as high as 60,000 pounds, without destroying germination ability, in tests at the West Virginia station. As organisms withstand as high a pressure, and spore-forming organisms even higher, the method seems to have no value for treating seeds for disease control.

Weed seeds buried 4 feet in the ground, at the Iowa station, showed vitality after the following lengths of time: Velvet weed, jimson weed, and horse nettle, 11 years; five finger, 10 years; curled dock and coffee tree, 9 years; tumbling pig-weed, 8 years;

burdock and catnip, 7 years; lambs quarters, 6 years; and field thistle, quack grass, dalea, evening primrose, and green foxtail, 5 years.

Vitamins for plant growth.—Studies of the bios requirement of baker's yeast, at the Minnesota station, showed that normal growth is impossible without something that appears to be of the nature of a vitamin but not identical with any of the known vitamins.

GENETICS

Inheritance in beans.—Crosses of a large-eyed bean and a small white bean, at the Maine station, showed large size to be associated with color, pattern, and pigmentation factors of the larger parent.

Inheritance of pericarp color.—Studies at the New York Cornell station, mainly with corn, showed pericarp color to be inherited in a strictly Mendelian way in some cases; and where it is not it may be due to the color being in the epidermis, which is not inherited.

Inheritance of nakedness in cotton.—Results obtained at the North Carolina station indicated that nakedness of cottonseed is a simple dominant character, in strains isolated from King; and it is believed it will be possible to produce upland varieties with naked seeds.

Color inheritance in sorghums.—At the Texas station, intravarietal crosses with yellow and white seed-coat colors, in milo, showed the yellow color to be completely dominant; in the case of red and white kafirs there was a blending of colors but no indication of hybrid vigor of growth, indicating that the different kafirs and milos are closely related.

Inheritance in cereals.—The Minnesota station finds that rust resistance in cereals is inherited as a single genetic factor. No correlation was found between inheritance of growth habit and reaction to rust.

Studies of wheat, at the Maine station, showed that in the einkorn group (*Triticum monococcum*) there are 7 pairs of chromosomes, in the emmer group 14 pairs, and in the vulgare group 21 pairs. Attempts are being made to combine the disease and drought resistance of the durum or emmer group with the bread-making qualities of the vulgare group by crossing the 14 and 21 chromosome groups. All of the intermediate hybrids from the cross are sterile, but all with 14 and 21 chromosomes are fertile, with good bread properties. All of the hybrids with an intermediate number of chromosomes either die or are sterile. The wild variety, with 7 chromosomes, is of no value. The 14-chromosome variety is adapted only to arid regions and is not very adaptable to other conditions. The 21-chromosome group is the most useful and widely grown; but although it is most variable and adapted to a wider range of conditions, it is not always the highest yielder. The members of the einkorn and emmer groups are found mostly in the regions where wheat originated. Certain varieties of *T. turgidum* of the 14-chromosome or emmer group are the most productive of all wheats. The size of the pollen grain is closely correlated with the chromosome numbers in the various species of wheat. In all crosses the F_1 plants are unusually vigorous and sterility is not due to poor vegetative development, but is caused by the formation of nonfunctional gametes.

Wheat-rye crosses, at the Georgia station, produced a progeny that was almost sterile.

Inheritance in phlox.—Large-eyed (*orbicularis*) phlox plants were found by the Pennsylvania station to be monohybrids, exhibiting segregation on self-pollination, into families that are one-half orbiculous, one-quarter small-eyed, and one-quarter astylis, the latter being a defective type. The character of singleness in flowers was sometimes completely dominant and at other times nearly recessive.

Inheritance of color in dairy cattle.—Crosses of Guernseys and Holsteins, made at the Illinois station, showed that in the F_2 generation red and black are all dimorphic, black being dominant to red, and segregation occurs in a 1:2:1 ratio. In 126 reciprocal matings of purebred Holstein and Guernsey parents, 119 black and white and 7 red and white offspring were produced.

Inheritance of plumage color in fowls.—At the Connecticut Storrs station, plumage color was found to be sex-linked and transmitted from mother to son. In barred feathers the rhythm may be due to one factor and the color to another, these being sex-linked. It is believed possible that egg production may be tied up with a color factor.

Inheritance of broodiness.—The Massachusetts station found that there is apparently no sex-linkage broodiness and that the character is transmitted by both parents.

FIELD CROPS

Cereals.—Studies on corn at the Nebraska station indicate that an in-

crease in kernel weight due to fertilization by foreign pollen may result either from heterosis or from a change in the type of endosperm. The increase from heterosis was marked in the case of selfed strains; but commercial varieties of corn, being heterozygous, responded relatively little to the immediate effect of foreign pollen. Studies at the Connecticut State station on the principles of inbreeding showed that it is as essential to control heredity through the pollen parent as through the seed parent. The loss of vigor in the F_1 generation was from 50 to 100 per cent, the line usually becoming extinct in three or four generations.

After 26 generations of selection for special characters, at the Illinois station, high protein strains averaged 17.33 per cent protein, low protein strains 7.41 per cent, high oil strains 9.86 per cent oil, and low oil strains 1.67 per cent. The high and low ear strains averaged 105.3 inches and 13.1 inches, respectively, in height of ear.

The phytosterols of corn oil and corn pollen were found by the New York State station to be different from those of other plants. The alcohol-ether extract of corn germ contained at least two phytosterols, one inactive, the other levorotary.

Fertilizer experiments with corn at the Georgia station showed that top dressing with sodium nitrate when the plants were about 2½ feet high gave better results than later applications. Marked effects resulted from the use of phosphates on corn at the Vermont station. Two applications were better than one, the second when the plant was in flower. Broadcasting commercial fertilizers ahead of the planter has given the best results in eight years' experiments at the Missouri station.

The New York State station found the popping quality of pop corn to depend upon variety, moisture content, and temperature of the popper. Varieties with small flinty kernels pop best, Japan Rice being one of the very best, its volume increasing from 28 to 31 times. Pop corn readily becomes too dry to pop well. The highest popping yields were obtained with corn having a moisture content of 13.5 to 14.5 per cent.

In studies of the lodging of grain, at the Ohio station, it was observed that with both wheat and oats there was a larger number of culms in the lodged area than in the upright. Thick seeding resulted in thin stem walls and a greater tendency to lodge. In thinner growths on poorer soils there was a higher carbohydrate content than in plants grown on richer soils, and the carbohydrate-nitrogen ratio was wider. Both fertility and method of culture had a marked effect on this ratio. An increase in moisture resulted in more straw and less grain and additions of available nitrogen increased tillering, stooling, and number of plants. Shaded areas, using only one layer of cheesecloth, showed more lodging than unshaded areas, both with wheat and oats. In the shaded area the carbohydrate-nitrogen ratio of the plants was higher than in case of the unshaded areas. The carbohydrates were higher in the unshaded stems, but there was considerable difference in varieties in this respect. Experiments with rye showed that the greater the tillering the weaker the straw. High nitrates in the soil favored lodging. There was more lodging on low ground, and plants from smaller seed showed a greater tendency to lodge. The thicker the stand the greater was the tendency to lodge.

Nitrate did not increase the yield of wheat at the Kentucky station when applied in the fall, and decreased the yield when applied in the spring, stimulating rank growth which made the plants more susceptible to disease. At the Arizona station an application of sodium nitrate on wheat (150 pounds per acre) increased the nitrogen content from 11.49 to 14.45 per cent. Late irrigations did not affect the nitrogen content. Barnyard manure (5 tons per acre) increased the nitrogen content very slightly. The yield was increased by nitrate of soda from 500 to 600 pounds per acre over plats receiving no fertilizer. Tests of time of applying nitrate at the Ohio station showed that the later the application was made in the spring the more protein there was in the grain. Experiments at the Idaho station showed that wheat following legumes increased in yield and in nitrogen content, owing to increased available nitrogen in the soil.

Rate and date tests of seeding winter wheat at the Utah station showed decided advantage in seeding not less than 5 pecks to the acre, and sowings made from September 15 to October 1 gave the highest yields. Wheat seeded in rows and cultivated gave significantly lower yields than like seedings uncultivated. In rate and date tests at the West Virginia station, 8 pecks per acre and seedings from September 20 to 30 gave

the highest yields. At the Montana station winter wheat seeded with the deep furrow drill produced 7 bushels more per acre than that sown with the ordinary drill and showed a survival of 87 per cent in the spring as against 51 per cent for the ordinary drill seeding. North and south seeding gave better yields than east and west seeding at the Kansas station.

The correlation between the calcium content of wheat and the pH value of the soil is usually very high, according to the Kansas station, but depends somewhat on the character of the soil, 0.1 per cent of calcium in a sandy soil having as great an effect as 0.6 per cent in a clay soil. A fairly close correlation between baking quality and water-soluble ash was found by the Nebraska station, the higher baking quality being associated with higher percentages of water-soluble ash. Environmental influences, particularly the weather, are dominant over soil differences in regard to yield, according to the Maryland station.

The awn plays a rather important rôle in the maturation of the wheat kernel, according to the Kansas station, bearded wheat showing a higher average weight of grain per plant and plumper kernels, as well as a higher yield.

The California station has succeeded in overcoming the foul condition which occurs in rice fields after three of four years of irrigating, by submerging the land after seeding to rice. Results obtained at the Louisiana station emphasize the advantage of rotating rice with an occasional crop of soy beans.

Potatoes.—Pure line selection with potatoes at the Montana station has shown that there are many distinct strains within varieties which differ materially as to yields, rate at which they run out, and resistance to disease, and indicates the need of systematic roguing or improvement work in order to keep varieties from deteriorating. Hill selection as compared with unselected strains, tried out on six different farms by the New York Cornell station, gave an average increase of 48 bushels per acre.

Relatively low temperatures during August and September are apparently one of the most important factors in producing good seed, according to the Nebraska station. Mulching was found to aid in maintaining the desired temperature. For best results the temperature of the growing season, from June 1 to September 30, should average below 67° F. Conditions in July and August are of special importance in connection with the late potato crop. Better seed was produced in dry-land areas than in irrigated regions. The West Virginia station found the practice of rubbing the sprouts off of seed potatoes to be disadvantageous. A study of place effect, in cooperation with the Minnesota station, in the production of potato seed stock, indicated no difference in yielding ability. At the New Hampshire station the yield from home-grown seed was 1.9 times less than that from the same strain grown in Maine.

Irrigated and nonirrigated seed potatoes showed comparatively little difference in value, in experiments at the Montana station, either on irrigated or dry land, provided the stock was equally free from disease. The most practical farm method for improvement was to pick out the best-looking plants in a field and from these in turn select and use the heavier yielding hills. Potato seed cut and planted the same day gave decidedly better results than did seed which had been cut some time previous to the day of planting. Cutting the seed 2 days before planting decreased the yield 60 per cent, and cutting 18 days before planting, 98 per cent. Second-crop immature seed gave better yields than matured stock, and cold-storage seed yielded much heavier than that from ordinary storage.

Treatment by submersion of the tubers, even after they had begun to sprout, in a solution of corrosive sublimate, 4 ounces to 30 gallons of water, for a half hour did not affect the stand at the New Hampshire station, and the use of salt with the solution was harmless.

In fertilizer tests at the New Jersey stations practically the same results were obtained from plats receiving all nitrogen in inorganic form as from those receiving half inorganic and half organic nitrogen. Five per cent of potash gave the maximum increase of yield. Fertilizer in direct contact with the seed reduced the crop 50 per cent if there was not much rain. The New Hampshire station found that liming potato land gave very unsatisfactory results, the potatoes on limed soils being 100 per cent scabby.

The deterioration of potatoes under irrigation, as compared with dry-land culture, was found by the Nebraska station to be largely due to one or more of the so-called virus diseases, the trouble being more pronounced

under irrigation than under dry-land culture.

Cotton.—A comparison at the Oklahoma station of the same seed on lowland and upland gave a staple one-eighth to one-fourth inch longer on lowland. In studies on the density of fiber growth on the seed coat, the North Carolina station found density to be closely correlated with weak tensile strength and soft textures.

Cotton planted at various rates and thinned when 2 to 4 inches high and also when 6 to 12 inches high gave a decrease in every case when thinned late at the Georgia station. At the Texas station medium-thick planting 6 to 18 inches in the row gave the highest yields. Deferred thinning decreased the yield as compared with thinning at the usual time. The Arizona station found that time and method of irrigation had more influence on maturity than methods of thinning. Topping in the middle of July apparently paid, but not when done the middle of August or later. The fuzz on upland cottonseed was found to retard the absorption of moisture; therefore, in order to get a good stand, it was necessary to plant such cotton deeper than the smooth-seeded kinds.

In experiments on the time of applying sodium nitrate, the Alabama station obtained the best results when one-fourth of the nitrate was drilled in the row at the time of planting and the remainder applied at the time of the first cultivation after chopping out.

Cotton on uncultivated plats matured early, and thus escaped boll-weevil injury to a considerable extent, in experiments at the North Carolina station. Growth ceased almost as soon as cultivation stopped. As wide variation was observed in oil content of the seed of the same variety on different plats as between varieties. Fertilizers did not seem to influence the oil content.

Tobacco.—Round Tip, a variety of tobacco originated by the Connecticut State station four years ago, a cross between Broadleaf and Sumatra and now extensively grown in the State and also in Florida, Porto Rico, and Venezuela, has been found to stand up well in the field, to be resistant to root rot, and true to type. Crossing of high-producing strains at the Pennsylvania station has resulted in several excellent types, among which are Hibshman Seedleaf, now extensively grown, Ramm Havana, which is very promising, and a more recent variety, Olson Seedleaf, which is attracting attention.

Tobacco grown after orchard grass at the Kentucky station, in a 4-year rotation of wheat, clover and orchard grass, orchard grass, and tobacco, gave considerably better quality of leaf than when following corn or other crops, and the average yield was better. In a 3-year rotation tobacco after redtop was decidedly better than after wheat or rape.

In experiments at the Pennsylvania station, an application of 1,500 pounds cottonseed meal, 300 pounds acid phosphate, and 200 pounds potassium sulphate gave equally as large yield and a better quality of leaf than heavy applications of manure either alone or supplemented with fertilizer.

Soybeans.—The Iowa station reports that the culture of soybeans is rapidly extending in the State. As an intercrop with corn it gives a large yield of silage material. Hogging down the crop was found to be less profitable than using it for silage. Of the varieties tested, Manchu, Peking, and Midwest have given good results, the latter two especially in the south. They grow well on acid soils. Manchu is best for hogging down and Peking for hay, silage, or sheeping down. Inoculation of the soil from time to time has been found necessary.

Soybeans alone produced higher yields of hay than when grown with millet, sorghum, or Sudan grass in experiments at the West Virginia station. Eight pecks per acre was the rate of seeding giving the highest yield. At the Wisconsin station a mixture of Sudan grass and soybeans yielded 2.4 tons of hay per acre and the digestible protein was 66 per cent greater than that of Sudan-grass hay alone. The mixed hay cured more readily than soybeans alone. It was found that varieties of beans differed in their relative susceptibility to inoculation and that the efficiency of the nitrogen fixation varied with the soil composition and reaction. Different strains of bacteria also varied in their nitrogen-fixing efficiency and in their power of producing nodules on the roots of the plants.

Experiments on the time to cut soybeans to get the best quality of hay, at the Ohio station, showed this to be when the pods are fully formed but before the beans are formed, the total nutrients being then highest. Early harvesting was better for the following wheat crop.

A great increase in interest in soybeans in the State is reported by the Missouri station, about 500,000 acres being planted in corn for hogging down. Soybeans grown in mixture with corn reduced the yield of corn, but their own yield more than made up for this loss.

Sorghums.—Marked increase in the height of F_1 hybrids and of succeeding generations was observed at the Kansas station. Forty-eight F_1 plants had an average height of 104 inches, while the average of the parents was only 65 inches. The decrease in vigor of sorghum crosses in generations following F_1 did not seem to be so rapid as with corn.

Gooseneck and Honey-drip sorghum gaves the largest amounts of silage at the Arizona station, but these varieties are coarse and Sumac sorghum is leafy. Of the nonsaccharine sorghums hegari proved best, giving more fodder than milo but not quite so much grain. Sorghum tended to make the soil stiff and lumpy, percolation tests showing that it took water about five times as long to go through such soil as through corn soil. Oats following hegari were inferior to the crop after cotton. Sorghum appeared to reduce accumulation of nitrates in the soil.

In experiments with kafir at the Oklahoma station, no culture or removal of weeds gave a yield of 12 bushels; scraping the ground to cut off the weeds, 25 bushels; and shallow culture gave but little more, as did deep culture, when it followed rain.

A dwarf feterita has been developed by the Texas station, comparable with dwarf milo. It is early and quick-maturing, which gives it an advantage where grain sorghums grow with difficulty.

Clovers, alfalfa, and other legumes.—At the Tennessee station it was found that American strains of clover were very much more susceptible to clover mildew than foreign strains, but much less susceptible to anthracnose. American strains gave slightly less hay from early cuttings, but the foreign strains were almost completely killed off by anthracnose soon after the first cutting, while the American strains made an abundant late crop of hay and survived the winter in good condition. At the Louisiana station all red clover from seed grown in the United States was badly affected with mildew, but that from foreign countries was only slightly affected. Both the New Hampshire and Indiana stations found the southern European clover to be unsuited to conditions in those States.

All alfalfa seed from high altitudes was found by the Colorado station to have a high hard seed content. This appears to be an hereditary character, but is associated with altitude. Turkestan alfalfa has a low hard seed content. Experiments at the Kansas station brought out the danger to the stand of alfalfa of too early and too frequent cuttings and the fact that delayed cutting does not injure the stand but tends to conserve it. The best practice was found by the Wisconsin station to be two cuttings a year and at as late a stage as possible without allowing the hay to become too coarse. In studies of the duty of water for alfalfa at the New Mexico station, this was found to be 4.67 acre-feet per acre, producing 5.47 tons.

Yellow Canadian Albotrae sweet clover has proved very satisfactory for hay and pasture at the Wisconsin station. Being fine-stemmed, with an abundance of leaves, it is more desirable than the ordinary white-blossomed sweet clover. Yields of from 10 to 12 bushels of seed per acre have been obtained. Sweet clover has proved a profitable pasture and green-manure crop at the Maryland station when grown between two crops of wheat, good pasture beginning when the plants were 8 to 10 inches high. Analysis showed the crop to be high in nitrogen and potash but low in phosphorus.

In tests at the Iowa station, to find legumes that would improve very poor acid soils, satisfactory growth with good nodule formation was secured with Mung beans, velvet beans, cowpeas, soybeans, Dalea, and an early strain of lespedeza

Wind and dust storms were found by the Washington station to be negligible factors in the distribution of legume bacteria. Drying out of soils during long, hot, dry periods of summer killed most legume bacteria in the soil. Seeds well inoculated with vigorous bacteria were found to be practically sterile at the end of six months' storage in a moderately dry place, showing that the inoculation of legume crops by persistence on the seeds from one season to another of viable legume bacteria does not generally occur. At the Illinois station none of 25 kinds of legume bacteria studied would cross-inoculate with soybeans, except possibly some strains of cowpea organisms.

Nodule formation was found by the California station to be correlated with soil temperature. In studies at the New Jersey stations maximum nodulation was secured in absence of fertilizer. Calcium appeared to be absolutely essential to nodulation. The higher the moisture content the greater the nodulation. At the Missouri station inoculated soils, exposed out of doors but protected from contamination, after five years still contained living legume bacteria. This indicates that a soil once well inoculated for soybeans or red clover will not need to be reinoculated if these crops recur in a 4 or 5-year rotation.

A newly distributed Hungarian vetch has been shown by the Oregon station to be exceptionally good for heavy, poorly drained land. Very early strains of Korean lespedeza tested by the Iowa station give promise of great value on poor acid soils for pasture and to prevent soil erosion. They give an unusually heavy, strong root growth and are very drought resistant.

Sugar beets.—Beets planted in September and October at the New Mexico station sent up seed stalks the next spring and produced abundance of seed. The maximum sugar content was reached during the latter part of August or in September. The smaller beets had the higher sugar content.

Sugar cane.—The Louisiana station reports that the benefit to the stubble crop of turning under clover was marked, an increase of 1.8 tons of cane being secured where clover was turned under March 20.

Sunflowers.—The Montana station secured the largest yield of sunflowers (26.12 tons per acre) by planting rows 36 inches apart and plants 4 inches apart. Early plantings produced the largest tonnage.

Silage.—At the Idaho station the composition and feeding value of sunflower silage appeared to be best when the plants were cut at the dough stage or just beyond, with about 80 per cent of moisture. When the plants were allowed to become too mature the silage was unpalatable. When the moisture content was over 80 per cent better silage was obtained by wilting to about that percentage.

There was an average loss of 7.59 per cent of dry matter during the ensiling process, in experiments at the Missouri station, the least loss being 4.01 per cent with fresh green corn and the largest 15.29 per cent with cereal crops. The average loss of protein for all crops was 5.44 per cent. There was an apparent gain of 5.94 per cent in ash. The crude fiber content remained practically unchanged. The nitrogen-free extract showed an average loss of 10.29 per cent. The loss in dry matter and of nitrogen-free extract of corn shocked in the field was approximately twice that in the silo.

Grasses and pastures.—Bahia grass (*Paspalum notatum*) has been tested by the Florida station in nearly every county in the State with good results. Dallis grass (*P. dilatatum*) and Vasey grass (*P. larranagai*) have proved to be the best two year-round wet, heavy land pasture grasses. Centipede grass (*Eremochloa ophiuroides*), a Chinese importation, bids fair to make an excellent lawn and golf course grass. Serradella shows some promise as a winter legume. Hubam clover has given good growth on flatwoods soil but poor on high pine land. As a soiling crop, Napier grass has given higher yields than corn or sorghum. Crotalarias give promise of being valuable green manure and cover crops, especially for orange and pecan groves.

In lawn-grass studies at the Rhode Island station, Rhode Island bent grass and red fescue have been found to possess great tolerance for soils that are so acid that they will not grow weeds, and to make a fine lawn especially for putting greens. Applications of ammonium sulphate bringing the acidity up to pH 4.5 are recommended as a top dressing to produce weedless lawns. It can be applied best in a mixture of 250 pounds each of acid phosphate, muriate of potash, and ammonium sulphate. More than this amount of acid phosphate tends to counteract soil acidity.

More than 300 selections of orchard grass have been made at the Virginia station, showing wide variation in form and earliness. One very promising strain has been isolated and is being increased for distribution.

Harding grass is proving valuable for pasture at the California station, being drought resistant and growing well with the natural rainfall of the State. In pasture fertilizer tests at the Pennsylvania station, grass generally predominated over clovers in high nitrogen plats, white and red clovers being crowded out. Clovers survived best in the struggle for existence on plats receiving a mixture of phosphate and potash with little or no nitrogen. The best growth was on the plats receiving all three elements.

In tests at the New Hampshire station, with the price of fertilizer high and of hay low, the average increase in yield did not pay the cost of fertilizer and the labor of applying it.

In very wet seasons good yields of hay were secured without top dressing. In very dry seasons the effect of the fertilizer was lessened. With an old turf, composed mainly of wild grasses, the increase in yield was not usually appreciable. With a comparatively new sod, in a normal season, with hay and fertilizers at a parity in price, nitrogenous materials, such as sodium nitrate or ammonium sulphate proved profitable.

Rotations.—The Utah station found two years of wheat followed by an intertilled crop to be better than having oats or barley serve as a second cereal crop. Corn after alfalfa showed thriftier growth than after wheat; wheat, on the other hand, often suffered severely after this legume. Alfalfa on dry lands gave best returns when allowed to remain on the same land longer than four or five years. A rotation consisting wholly of annual crops and without manure was very exhausting. A rotation including alfalfa and manure maintained the soil in high productivity. Light applications of manure were of more value than heavy, but 40 tons per acre per year was not excessive for sugar beets and was an effective means of combatting blight (*Phoma betæ*). Sugar beets were more susceptible to blight when following some other crop than sugar beets. A green-manure crop of field peas was not effective in increasing the yield of a succeeding sugar-beet crop.

The Kansas station found that wheat following alfalfa contained 3 to 4 per cent more protein but weighed less per bushel than that following bromegrass. In rotations, shallow plowing seemed as effective as deep and gave as much nitrification.

In eight years' experiments at the Indiana station, wheat following soybeans averaged 31.4 bushels per acre as compared with 24.5 bushels after corn. The least profitable rotation has been corn, oats, clover, yielding $22.68 gross returns per acre per year. The largest returns have been secured from a 6-year rotation of corn, corn, wheat, and three years of alfalfa, which has averaged $34.81 per acre per year.

Potatoes grown in rotation following alfalfa at the Wyoming station produced almost double the yield of those grown on soil that had been continuously in grain, and were less scabby.

Ten years' study, at the Montana station, of the residual effects of crops showed that sugar beets preceded by flax averaged a larger tonnage than when following any other crop. The lowest average yield was secured when beets were preceded by wheat or oats. The average acre yield of corn ranged from 35.1 bushels when following oats to 60.9 bushels when following alfalfa. Yields of wheat were greatest when following beets, averaging 33.2 bushels. The highest average yield of oats was obtained when this crop followed beets.

Residues from sorghums were found by the Arizona station to hinder the growth of wheat, corn, and hegari to a much greater extent than did those from corn. Applications of 40 tons per acre of residues from either corn or sorghums hindered the growth of wheat, as compared with no treatment. Tests at the Rhode Island station show that corn following potatoes or mangels was poor, but following onions or carrots was good.

Weeds.—The Iowa station estimated that the annual loss from weeds in the State is $25,000,000. Tests showed that a mixed culture of weeds and grain transpired more moisture under the same conditions than a grain crop alone. The Kansas station found the prevention of weed growth to be the main factor in preparing for a crop of wheat. Scraping the surface to keep down weeds gave nearly double the yield of no treatment.

HORTICULTURE

Orchard management. — Investigations at the Massachusetts station showed that, in a bearing orchard, sod with applications of sodium nitrate gave the best results; but that, in a growing orchard, cultivation without fertilizers was better. Plats that were mulched had a better appearance and greater leaf area. Those receiving a complete fertilizer were slightly better than those with phosphorus, potash, and lime, with clover. In an old fertilizer-test orchard started many years ago, the unfertilized block is practically of no value while the others are still bearing. In a bearing orchard, limiting the nitrogen supply has resulted in poor color of fruit rather than in affecting productiveness. Fertilizer experiments in a pear orchard indicate that the requirements are the same as for apples, but the effects are not so marked.

In a comparison of orchard plats continuously in sod and those with rye as a cover crop, at the New York Cornell station, nitrates were always low under the sod, except where large quantities had been recently applied, and tree growth was greatest in the

sod plats that received the largest amount of nitrate. The removal of moisture from the soil by grass was not an important factor in tree growth, the determining factor being evidently the maintenance of an adequate supply of nitrate nitrogen. The injurious effect of sod on the growth of young apple trees was reduced by the annual application of half a pound of sodium nitrate per tree. Trees in sod plats receiving nitrates showed vigorous terminal growth but few strong branches as compared with trees on cultivated plats. Trees in sod receiving no nitrates had relatively heavy roots as compared with those on cultivated plats, but the roots of trees on sod plats receiving heavy applications of nitrates constituted a much smaller part of the total weight of the tree. The roots of trees in the cultivated plats were more fibrous as compared with those on sod. It is believed that there has been an overemphasis of the importance of cultivation. Timothy evidently hindered the growth of the tree by reducing the available nitrogen. No confirmation has been noted of the toxic action of grass on trees.

After 14 years of orchard treatment at the Delaware station, results show that as long as all three elements are present the proportion does not make much difference. Ten years' results at the Michigan station show that trees growing vigorously are not helped by the use of fertilizers, but poor growing trees can be brought up, especially apple and cherry; and the same applies to strawberries.

Orchard studies at the Illinois station demonstrated that the peach crop may be increased by 158 bushels per acre in soil typical of the peach districts at a cost of $25 per acre for labor, fertilizers, or other equivalent care, and that the application of nitrogenous fertilizers in the apple orchard may increase the crop in a typical apple soil 27 barrels per acre at a cost for labor, fertilizers, or equivalent care of $15 per acre. Fertilization of a commercial orchard showed an increase of 30 barrels per acre as a result of treatment. Applications of nitrate of soda and the use of cowpea cover crops were profitable. Mulching with grass and legumes grown in the orchard between the trees was more profitable than clean cultivation.

Nitrate of soda and straw mulch on straight sod have given marked increases for two years at the Indiana station. Cultivated trees have made the most growth and largest yields.

Nitrogen applied in the fall is stored in the tree, according to the Missouri station, the nitrogen content of the spurs being higher the following spring. Spring applications of nitrogen decreased the starch accumulation in the spurs in June; fall applications increased it in the following June, tending to influence fruit bud formation. Spring applications increased the blossoms, for which reason it is recommended to apply spring applications only in the off year, and fall fertilizers in inverse proportion to the yield of that year in order to overcome an off-year crop. This course has been very successful with York Imperial, a persistent off-year bearer.

Trees in sod at the Pennsylvania station made very large gains from the addition of nitrogenous fertilizers; but trees under cultivation made no response to fertilizers when a good cover crop was grown each year and plowed under in the fall or early spring. Five pounds of nitrate of soda applied to each tree about two weeks before the flower buds break has given as good or better results than 10 pounds applied after blooming is over.

Nitrate of soda applied to blue grass cover crops in orchards increased fruit production at the Iowa station. Winter injury was increased under clean culture.

Apples.—In the pollination of apple orchards, the Maine station found that if honeybees were absent, bumblebees pollinated just as well. There was no evidence that wind was effective in pollinating apples. Commercial varieties of apples grown in Maine are practically self-sterile and must be pollinated with pollen of compatible varieties. Delicious was found to be especially well suited as a pollen variety for McIntosh, Ben Davis, and Baldwin. Wealthy was also found to be especially compatible with McIntosh. Trees of the same age and under the same conditions vary largely in productivity. This is apparently closely associated with a definite type of habit of growth, the productive type of tree being large, open, and spreading, with short laterals and many spurs, while the unproductive type is small and upright, with slender branches and few spurs. Of 881 trees in a Ben Davis orchard, 29 per cent were found to be of the unproductive type, and were kept at an average

loss of 90 cents per tree, while those of the productive type were kept at an average profit of $2.20. The primary causes of differences in productivity in fruit trees may be attributed to soil, root stocks, or differences in cions. Soil played an important part as indicated by the natural grouping together of unproductive trees, and about 35 per cent of these could be attributed to unfavorable root stocks and cions. There was a direct relation between early growth and yield and a correlation between trunk measurement and yield, but the root system was the main factor.

Dropping of fruit early in the growing season was found by the Wisconsin station not to be due to lack of pollination but to nutritional factors. Trees properly pruned and fertilized, so that the bearing top was in good vegetative condition, suffered least from loss of fruit. Noting the period between injury to fruit and dropping with apples, peaches, and plums, the Delaware station found this to grow shorter as the fruit increased in size, being at first 14 days, gradually dropping to 7 or 8 days, and then to 3 or 4 days. It was found that the first wave of drops was of winter buds.

Certain varieties of apples, as Jonathan, Stayman Winesap, Delicious, King David, and Wagener, were observed by the Washington station to ripen on the trees before attaining the desired color; and such factors as color of fruit or seed, size of fruit, or ease with which it breaks from the stem, or combinations of these, could not be used as a safe guide in determining when these varieties should be picked.

The strength of an apple-tree crotch was found by the New York Cornell station to vary directly with the width of the angle between the arms, crotches with equal arms splitting more easily than those with unequal arms. The critical age at which crotches break was just as the tree was coming into bearing.

Experiments in storing apples at the Iowa station indicated that the best way to keep Grimes Golden apples and to avoid scald and internal breakdown was to pick the fruit when fully but not overmatured and to wrap it in an oil covering containing at least 15 per cent of oil by weight. Soft scald was closely associated with maturity.

Peaches.—Breeding work with peaches at the New Jersey stations has resulted in the development and introduction of a white-fleshed variety, the Pioneer, which is earlier than Carman and superior to it in appearance, form, and quality; and the tree is fully as vigorous, hardy, and productive. An early yellow-fleshed variety has also been developed which is equal in quality to the best midseason yellows.

Leguminous cover crops, especially cowpeas, were found by the Illinois station to have an injurious effect on the peach, but this could be corrected by the use of potash. With no cover crop of legumes, nitrogen was the best fertilizing element for both trees and fruit. Fertilization of peach trees with a combination of potash and nitrogen or with stable manure increased the yield over unfertilized plats by 251 bushels per acre.

The importance of thinning peaches early and severely has been emphasized in experiments at the New Jersey stations. The largest and best fruit was produced on trees from which 50 per cent of the fruit had been thinned off early in June. At the West Virginia station, summer pruning of the peach the first fruiting year gave good results, but after that pruning should be light.

In investigations on hardiness of the peach at the Maryland station, the "moisture index," which is the quotient obtained by dividing the moisture content of fruit buds by their dry weight, was found to be low in winter but increased with advance of spring, and appears to be correlated with bud hardiness. Fruit buds were found to depend directly on the roots for their moisture in early autumn, whereas in midwinter the tree was the source.

The peach contains starch and reducing sugar but little if any sucrose in the early stages of development, according to the Delaware station. As the fruit approached maturity, the reducing sugars declined steadily, becoming finally almost constant between 2.25 and 2.75 per cent. The starch content became very low and sucrose increased steadily as the fruit ripened. As the so-called "dead ripe" stage approached, the sucrose content decreased rapidly with a corresponding increase in reducing sugars.

Pears, plums, and prunes.—Bartlett pears differ as to fertility and sterility in different sections and elevations, as brought out by investigations at the California station. In interior valleys they are self-fertile, but above 2,500 feet they are self-sterile. It is found that pears may be retarded in ripening at temperatures above the optimum. The Pineapple pear, a variety highly resistant to fire blight, which the Georgia station has been

testing for 15 years, is attracting much attention.

A pronounced correlation between resistance of the plum to brown rot and crude fiber content was found by the Minnesota station. Varieties containing 6 per cent or more of fiber were comparatively resistant, while with less than this amount, on the dry basis, they were susceptible.

A method of drying prunes with a recirculating air drier devised by the Oregon station has reduced the cost per pound for drying from 2.5 to 1.2 cents and is being widely used.

Cherries.—All varieties of sweet cherries were found by the Oregon station to be self-sterile and Bing, Lambert, and Napoleon to be intersterile. The varieties most suitable for pollination purposes were Republican, Black Tartarian, Centennial, and Governor Wood.

Citrus fruits.—Investigations at the Arizona station on the effect of cover crops on humidity and temperature in citrus orchards in relation to June drought show that the atmospheric temperature was lowered by cover crops 2.5° F. during the winter and 7° during the summer, and that soil temperature was 2.5° to 3° warmer in winter and 6° to 7° cooler in summer at a depth of 12 inches. The air humidity was 10 to 12 per cent higher in cover-crop orchards, and evaporation was considerably less than in others. A study of the root systems of citrus trees showed that the majority of the feeding roots of the orange and grapefruit were in the first 2 feet of soil.

According to the California station, the June drop of citrus may be largely prevented by care in cultivation, irrigation, fertilization, and pest control. Finely powdered calcium cyanide was found to be an excellent fungicide for citrus trees.

In study of the effect of potash on the orange the Florida station found a little higher percentage of sugar where 10 per cent potash was applied, but with only 3 per cent no difference was apparent, as the result of two years' applications. There was earlier ripening of oranges where no potash was applied, but the fruit was somewhat smaller.

Dates.—A successful method of propagating the date has been devised at the Arizona station, consisting in maintaining a moist rooting medium about the base of the offshoot without detaching it from the mother palm for a period of six to eight weeks, at the end of which time it will have developed roots.

Grapes.—A very promising new grape has been found by the Arizona station for the southern part of the State, with a high color, excellent flavor, and fine shipping quality, which is immune to the attack of June bugs. There are few varieties in southern Arizona that combine so many desirable commercial features. The station found that a light soil gives sweeter grapes than a heavy soil.

Experiments with rooting cuttings of *Vitis rotundifolia* at the Georgia station indicated that winter cuttings are best, no summer cuttings having formed roots. At the Illinois station roots of the grape were found to extend to a radius of 23 feet and to reach a depth of 9 feet.

Cane-pruned vines have given better results at the Nebraska station than spur pruned in the percentage of buds that produced fruit, in the number of clusters produced, and in the size of the clusters.

The pigment in dark blue grapes was found by the New York State station to be a monoglucosid, splitting on hydrolysis with acids into glucose and the color base.

Small fruits.—Raspberries with straw and manure gave an increase of over 50 per cent in production over unmulched vines, at the Illinois station, and the berries were of better quality and firmer. Foliage was retained longer on mulched gooseberries and currants than on unmulched.

In experiments with brambles, the Massachusetts station found that sulfate of potash produced hardier plants than the muriate and also gave better color and vigor.

Strawberries responded better to sulfur than to phosphorus applications, in experiments at the Missouri station.

Winter injury and hardiness of fruits.—Tests with apple seedlings at the New Hampshire station showed that if these are frozen and placed in a warm place at once they are severely injured, but if they are kept at 0° C. for a month or more fairly good results are obtained. The top parts of the roots of seedlings were found to be hardier than the lower parts. No correlation was found between the size of root and the injury done. Frozen roots that were not injured grew faster than unfrozen checks. The xylem cells were first discolored, then the phloem, this being shown by dark rings on cross sections of roots. Those showing a double ring on cross section were markedly injured, while

those showing a xylem ring only inside the cambium, were not injured. Injury increased with the length of exposure to low temperatures, and the injury was more severe with quick freezing than slow. When roots were dried for 24 hours they became more resistant. Freezing injury was due to the exhaustion of water from the protoplasm. When plants were frozen in sand the amount of injury increased with the quantity of water present. A difference in root hardiness of varieties was found, Duchess and Hibernal proving to be the most hardy in a 3-year trial. The latter may be used as root stock to advantage, but Duchess has no value for this purpose. In freezing, water went out of the cells and froze in the intercellular spaces. Drying gave practically the same effect as freezing. Seedling roots imbedded in sand, both dry and containing different quantities of water and subjected to a temperature of —8° C. for nine hours, showed about 13 per cent less injury in dry sand than in wet or medium moist sand. There was found to be no greater tendency for small roots to be injured than large ones of the same age. Small young roots, however, were found by the Nebraska station to be more susceptible to cold than larger, older ones. The tops of some varieties of apples were found to be more subject to winter injury in the nursery than others. The moisture content of orchard soil did not greatly influence the minimum temperature that was reached in midwinter at several inches below the surface. Freezing temperatures were reached somewhat sooner in early winter in dry than in wet soil; but in early spring wet soil remained at or near the freezing point, while the dry soil had a mean temperature of 34° F. Wide variation was found in hardiness of apple stocks to winter injury.

The Missouri station found a correlation between the rate at which tissues dry in the oven and hardiness, hardy tissues drying more slowly owing to the water being held in a colloidal condition.

Fruit bud formation.—Buds of the gooseberry and currant were found by the New York Cornell station to differentiate into flowers for the next season, about the middle of August. Blackberry buds showed the differentiation early in September and black and red raspberries did not clearly differentiate until early spring. In bramble fruits all buds appeared to be potentially fruit buds.

Studies of the effect of blossom bud formation in plums at the Wisconsin station showed that partial or complete early defoliation had a marked inhibiting effect, and buds and spurs formed at the defoliated nodes were noticeably smaller than the average, there being evidence of mass or cumulative influence on bud formation extending into the next season. The defoliated nodes contained decidedly less nitrogen than those not defoliated.

Data secured at the New Hampshire station showed that during the period of most active fruit bud formation, the spurs on the nonfruiting sod plats, 10 per cent of which formed fruit buds, were lowest in total nitrogen; those on fruiting sod plats, none of which formed fruit buds and those on the nonfruiting nitrate plats, 44 per cent of which formed fruit buds, were medium in nitrogen content; and those of the fruiting nitrate plats, 0.5 per cent of which formed fruit buds, were highest in nitrogen. At the same time the spurs from the nonfruiting sod plats were highest in starch, those from the nonfruiting nitrate plats, medium in starch, and those from the fruiting sod plats and fruiting nitrate plats were lowest in starch. An examination of the starch and total nitrogen for the entire season showed that the spurs from trees grown in sod were in general lower in total nitrogen and higher in carbohydrates than the spurs from trees grown on the nitrate plats.

Fruit products.—The California station found that fruit can be frozen solid and kept in fresh condition without loss of flavor for a year or more. The texture is injured somewhat, but it is fully as good for jams, ice cream, and other purposes.

In studies on fruit jellies at the Delaware station, the essential factors in jellying were found to be pectin, sugar, and acid. The formation of fruit jellies was not correlated with total acidity but with active acidity or hydrogen-ion concentration, the minimum hydrogen-ion concentration at which jelly formed being pH 3.46. Jelly formation occurred irrespective of the quantity of pectin present when the minimum hydrogen-ion concentration was reached, but there was a minimum amount of pectin necessary to produce jelly. With pectin, sugar, and water maintained constant, the character of the jelly formed was determined by the hydrogen-ion concentration, the jelly becoming stiffer as

this increased. Tartaric acid was the most efficient of the acids that are commonly present in fruit juices used for jellies, malic acid being next and citric acid least efficient. A study of the sugar factor showed that the quantity of this could be varied over a wide range, but the percentage of sugar in a finished jelly was fairly constant, being approximately 70 per cent by weight. Increasing the hydrogen-ion concentration increased slightly the percentage of sugar in the finished jelly. The least percentage of sugar possible for jelly formation was 64.1 per cent, but jellies made with the lower percentages were tender and weak, regardless of the hydrogen-ion concentration. Jelly formation may occur in the presence of a saturated solution of sugar. The sugar-holding capacity of a jelly increased materially with increase in hydrogen-ion concentration. At pH 3.4 it was not possible to add more than 125 to 130 grams of cane sugar to 2 grams of pectin and produce a jelly, but at pH 3.1 a jelly could be formed upon the addition of 170 to 180 grams of sugar to the same amount of pectin. Jelly formation appeared to be a precipitation of the pectin in a saturated or nearly saturated solution of sugar, the precipitation being determined by the hydrogen-ion concentration.

Vegetables.—Tests with asparagus at the Rhode Island station showed that on soils of the same reaction sodium chloride is more useful than the carbonate in replacing potash.

Studies of inheritance of size of beans at the Maine station showed that all pigmented varieties are larger than nonpigmented and there appeared to be a definite linkage. Resistance to mosaic was also found to be linked up with color and size. F_3 families were all found to be either resistant or susceptible, showing segregation. Results with Lima beans at the Illinois station showed that the inoculation of seed with pure cultures of the bacillus which causes nodules on cowpeas increased the yield of beans.

Tests with cabbages at the Pennsylvania station indicate the water-holding capacity of the soil to be a leading factor in regulating the solidity of the heads. The presence of considerable amounts of sand in a soil led to the production of larger roots and smaller tops than was the case in rich soils. It was found that, with cabbage, treatment which gave the largest total yield also gave the largest early yield and the greatest production of early heads; but with the tomato, the largest proportion of early fruit, though not the heaviest weight, was always obtained from half-starved plants. The total yield may be reduced by frost if a fertilizer is applied that produces very heavy foliage growth, under which the fruit ripens slowly.

In seed-bed plantings of celery from December 10 to February 25 at the New York Cornell station, some were frozen and some died; but all the early plantings went to seed regardless of treatment, freezing and drying having no effect.

Experiments in the forcing of Witloof chicory at the Illinois station indicated that medium-sized roots are best for this purpose; and although freezing causes them to rot, they may be held in storage at 31° F. to keep them dormant and are then in excellent condition for forcing.

Applications of acid phosphate were found to hasten the maturity of lettuce by three weeks at the Arizona station.

Muskmelons started under glass at the New Jersey stations showed a gain of two weeks in time of ripening over those from seed planted in the field and gave an increased yield of about 750 melons per acre.

Experiments on the irrigation of canning peas at the Utah station showed that two irrigations instead of one increased the yield 51 per cent and three irrigations 92 per cent.

Experiments in forcing rhubarb at the Illinois station indicated that differences in temperature had a marked effect on the yield and color and that differences in watering influenced the development of the crop. The quality of forced rhubarb was much superior to that grown out of doors.

Sweet corn crosses, Black Mexican and Golden Bantam with Crosby, have given excellent results in the F_1 generation at the Maine station. Observations at the Indiana station showed that large and small kernels within a variety caused a variation of about five days in time of reaching the canning stage, the corn from larger kernels being earlier, more uniform in maturity, and slightly heavier in yielding ability than that from the smaller kernels.

Studies of the changes in the amount and character of the carbohydrates in sweet corn and methods of accurately determining these were reported by the Maryland station. Sugar and starch and the relative proportions of these two in early and late corn at different stages of growth were determined and the rates of

ripening at the prevailing mean temperatures were definitely worked out as a basis for forecasting the date and duration of the best canning stage for sweet corn. It was found that the reliability of the nail test was dependent largely upon the rate of ripening and of loss of water by evaporation. The rapid deterioration of corn in warm weather after it had reached its prime condition for canning was shown.

Sweet-potato fertilizer tests at the New Jersey stations showed the organic sources of nitrogen to be equal to the mineral sources from the standpoint of yield. Sulfate of ammonia proved to be superior to nitrate of soda. Potash was a very essential element. The fertilizer mixture as well as moisture conditions had a marked influence on the shape of the sweet potato. At the Arizona station pruning sweet-potato vines, as is commonly practiced, was found to reduce the yield 50 per cent.

At the New Hampshire station, potash used in connection with phosphoric acid on tomatoes delayed maturity and decreased yields, there being an increase of only 9.4 per cent over the check, compared with 141.8 per cent where acid phosphate was used alone.

Walnuts.—Moldy nuts were found by the California station to result from allowing them to remain in the husk after they were ripe. Proper irrigation corrected this, causing the nuts to drop out early, giving less "stick tights."

Hydrangeas.—The determining factor in the color of hydrangeas was found by the New Jersey stations to be the reaction of the soil solution, an alkaline soil giving a pink color and an acid soil a blue.

Tung oil trees.—Experiments at the Florida station showed that seed of the tung oil tree should be planted in late January or in February to avoid frost injury to the young plants. Ordinary methods of root cuttings proved almost a complete failure, but both patch and sprig buds made good union and subsequent growth. Three insect pests have been observed, the cottony cushion scale, *Lantana* sp., and nematodes. The great variation in the bearing qualities of this tree makes successful budding especially important, as it makes possible the propagation and planting of trees of known bearing character.

Pruning.—In a study of the physiology of pruning at the California station, it was found that pruning weakens the concentration of the sap by stimulating vegetative growth, and high concentration bears a relation to fruit setting.

Observations on pruning at the New York Cornell station indicated that cutting off low limbs reduced bearing from one-third to one-half.

Spraying and dusting.—A dry-mix sulfur-lime has been developed by the New Jersey stations as a summer fungicide for tree fruits that is being widely used with much success, largely taking the place of self-boiled lime sulfur.

A spreader consisting of 1 gallon of sour milk and 2 ounces of bicarbonate of soda added to 200 gallons of lime-sulfur mixture gave as satisfactory results at the Iowa station as commercially prepared caseinate and was much cheaper.

Experiments with radishes under normal, light, and heavy shading at the New Hampshire station showed that shading did not increase the sensitiveness of the plant to Bordeaux, and the degree of alkalinity of the Bordeaux had no material effect.

DISEASES OF PLANTS

Apple Diseases.—Studies on the control of blister canker at the Iowa station have shown the best treatment to be to cut out the canker with a gouge and mallet and paint the wound with white lead and linseed oil, to which is added 0.5 ounce of powdered mercuric chloride to each 2 quarts of paint. Ordinary roofing paints may be used, as the coal tar base of these seems to be very toxic to the blister canker fungus and does not hurt the freshly cut bark. The New York Cornell station reports a new Fusicoccum canker of the apple, affecting nursery stock in storage and trees in the orchard. A new species, *F. pyrorum*, is found to be the cause.

Satisfactory control of apple blotch was secured at the New Jersey stations with two applications, in addition to the regular spray calendar, of commercial concentrated lime-sulfur, 1:40, made at 7-day intervals following the fifth summer spray made four or five weeks after the petals fall. The Indiana station, on the other hand, reports that lime-sulfur is not so reliable as Bordeaux, of which even the weaker mixtures prove effective for the control of this disease.

The organism *Sphœropsis malorum* has been isolated from frog-eye of the apple by the Pennsylvania station, but artificial infection has not been successful. The use of lime-sulfur spray reduced the disease from one of the worst to one of minor importance.

In studies of apple measles at the New Mexico station, no organism was isolated and the trouble is thought to be one of nutrition or lack of moisture, accompanied by accumulation of salts. Attempts to transmit the disease by inoculation and grafting were not successful.

Cedar rust, the alternate form of apple rust, has been successfully grown by the West Virginia station on infected cedar leaves removed from the tree and kept in an ordinary nutrient solution containing glucose. Such cultures have been kept alive for four months.

Field and greenhouse studies on apple scab at the Wisconsin station show that temperature and moisture cause important variations in the development of the causal fungus and in the susceptibility of the host plant at critical periods, as well as in the inception and development of the disease and the action of the fungus. The addition of a prepink application of a suitable spray to the usual program has given satisfactory control. The importance of the prepink spray was also emphasized by results obtained at the Michigan station. At the Massachusetts station, lime-sulfur and Bordeaux, if thoroughly applied as a spray, gave 100 per cent control. Dusting did not control the disease. Copper fungicides burned the foliage, but could be used up to the pink spray, after which lime-sulfur was best. Sulfur was not effective at low temperatures. Results of two years' work at the Pennsylvania station showed the superiority of lime-sulfur sprays over sulfur dusts in controlling the scab. The most effective sprays were those containing nicotine as well as lime and sulfur. The experiments also emphasized the necessity of timely spraying, especially the value of a prepink spray. At the Virginia station it was found that rainfall is necessary to bring about the discharge of ascospores.

Seedlings of known fire blight resistant stocks of apple, pear, and quince at the Tennessee station, open fertilized in an orchard containing susceptible varieties, exhibited a high degree of resistance, indicating that this factor is dominant.

Pear Diseases.—Studies on pear leaf spot at the New Jersey stations indicated that four summer applications of self-boiled lime-sulfur, in addition to the petal fall spray for the curculio and codling moth, will give satisfactory control of this disease.

The pear blight organism was found by the California station to occur in the outer bark rather than in the cambium, and it may therefore be killed without injury to the tree. The best results were obtained with zinc chloride applied after scraping off the rough bark, as a 50 per cent solution, with the addition of glycerine to prevent drying.

Studies on European canker at the Oregon station show it to be particularly destructive to thin-barked pear trees and it spreads rapidly. A fair degree of control was secured by spraying with Bordeaux previous to the fall rainy season. The early spore stage has been found in young cankers, which helps diagnosis.

Peach yellows.—Studies on this disease carried on at the Delaware station showed that the carbohydrate synthesis of "yellows" wood is not materially different from that of normal wood, but there is a retardation in the diseased host of the utilization of the carbohydrate products previously formed. In 2-year yellows wood there was a more pronounced and permanent deposition of gum in the medullary rays. The cellular units in the diseased plant were smaller and the tissues in the wood and leaf were greatly reduced in comparison with the normal. No infections resulted from inoculations of infusions of fruit, leaves, and limbs of diseased peaches, indicating that the disease may be carried otherwise, and possibly the causal organism may go through a part of its life in some insect. Pollen from infected trees, when applied to healthy trees, failed to set any fruit. It is believed that the curculio may be closely connected with the trouble.

The Verticillium causing eggplant wilt is, according to the New Jersey stations, apparently the same as that found on okra and on the peach, although transfers from the peach were not successful. The disease appears to be most severe on alkaline soils. If infected limbs and trees are cut out of a peach orchard, it disappears.

Cherry leaf spot.—It was found at the Wisconsin station that the causal fungus of this disease passes the winter in old leaves on the ground, and in the spring produces spores which pass through the air to the cherry. It was found to be unnecessary to apply the preblossom spray formerly considered to be essential by some growers.

Citrus diseases.—Studies at the Florida station showed that citrus seed infected with citrus canker organisms did not produce canker-infected plants. The longest time the organism was observed to live in unsterilized soil

was one week, but it lived and remained viable for many months in sterilized pine shavings and was observed to live for some time in both sterilized and tap water. Spores of the organism in cultures over a year old were still alive and viable. Some evidence was secured indicating that bees may act as carriers of the disease. In studies on the control of citrus melanose and stem end rot, at the same station, one application of a spray of 3–3–50 Bordeaux plus 1 per cent oil emulsion, applied from 10 to 20 days after the blossoms had fallen, more than doubled the number of bright fruits. The cost was from 8 to 13 cents a tree and there was a net gain of 50 cents a box profit from spraying.

The cause of the internal decline of lemons was found by the California station to be abnormal water relations, due to withdrawal from the fruit by the leaves during hot summer months. Even under heavy irrigation the leaves could not pump water up fast enough and in hot winds they wilted. Internal decline after picking or in transit is thought to be an Alternaria rot induced by any weakness in the lemon. Infection occurred in the early stages, the mycelium working its way into the fruit. It did not grow in the green lemon, but as soon as physiological changes took place in storage it started.

Disease resistance in plums.—An examination of 11 varieties of plums at the Minnesota station, in relation to resistance to the brown rot fungus (*Sclerotinia cinerea*) showed that those varieties containing 6 per cent or more of fiber on the dry basis were comparatively resistant and those containing a less amount were susceptible.

Diseases of vegetables.—A new organism was found in the bacterial spot of Lima beans by the Wisconsin station, which has been named *Bacterium viridifaciens*. All varieties of Lima beans tested were susceptible. The disease was especially severe with heavy rainfall and a moderately high temperature. It is believed to live over winter in seed and refuse. Data secured at the New York State station showed that the date of planting bears an important relation to the susceptibility of beans to bacterial blight, late-planted beans suffering less than early-planted. The Colorado station found much difference in the susceptibility of varieties of beans to bean rust. Several pintos were almost immune.

Cabbage yellows has been extensively studied at the Wisconsin station. The organism, *Fusarium conglutinans*, was found to be especially destructive in hot, dry weather, with little or no development, even on the "sickest" soils, in cool, moist weather. The optimum temperature for the fungus was found to be 25° to 27° C. A soil moisture content of 15 per cent was most favorable for this fungus and 19 per cent for the growth of cabbage seedlings, in a soil having a water-holding capacity of 46 per cent. Early seeding insured most favorable conditions for resistance to the disease. All plants remained healthy in a sick soil, below 17°, many were resistant at 17° to 23°, and some at higher temperatures. Susceptibility to disease increased with age.

Studies on the downy mildew of the cantaloupe at the Delaware station showed that the effects produced by the fungus causing this disease, *Pseudoperonospora cubensis*, is apparently the result of a toxin, perhaps an enzym. Light, even dustings with copper salts, arsenic, or nicotine controlled it except when weather conditions favored the disease.

In investigations on carrot blight at the Massachusetts station, an organism, *Cercospora apii carrotiæ*, was found and grown in cultures from which the disease was reproduced. The fungus did not germinate if immersed in water, but in a moist atmosphere it germinated at 20° C. It was very resistant to copper fungicides.

Cauliflower black rot appeared, from studies at the New York State station, to survive and be carried over winter on white cabbage and Brussels sprouts, the cauliflower itself not surviving the winter. Plants grown to maturity under cheesecloth largely escaped the disease, while those not so protected were severely attacked. Spraying the plants in the seed bed or field with Bordeaux injured them.

Satisfactory control of lettuce drop was secured by the Massachusetts and Pennsylvania stations by treatment with commercial formalin, which also stimulates the plants, 4 pints to 50 square feet of soil in the coldframes being recommended by the latter station.

The fungus causing onion smut was grown in media ranging from pH 3.5 to 9.5 at the Massachusetts station, showing that acidity is not the controlling factor. By using a stronger formaldehyde solution than has been recommended, as high as 95 per cent, good control was secured.

In studies on pea root rot at the New Jersey stations, seven organisms were found, including two Fusaria, a Rhizoctonia, and unidentified organisms. It appeared on the roots soon after the peas were up, as a rule, and its most injurious effects were noted at blossom time. It may be carried from field to field by soil particles and the organism may survive in the soil for long periods without peas. It was worse on light soils. As yet no control has been found. The Utah station isolated four species of fungi from this disease from infected soil, including *Corticium vagum*, *Pythium* sp., and two Fusaria, but it is not believed that these are responsible for the major part of the trouble found in the field. Later a fifth species was found, an *Aphanomyces* sp., which it is believed is mainly responsible. This organism causes a hardening and yellowing of the peas and lowers the grade. The station also found two fungi associated with pea black leaf, a Fusicladium and a Phyllosticta, which appear to be forms of the same fungus. All attempts to cultivate the causal organism have failed.

Studies of the crown rot of rhubarb from four localities by the Pennsylvania station showed it to be caused by different species of Phytophthora, but that *P. cactorum* is the only species present in Pennsylvania. Setting disease-free roots in a new location is the most practical method of control.

A new species of spinach wilt, caused by *Fusarium spinaciæ*, was found during the year by the Idaho station. It destroys the root system of the plant. The Texas station reports that this disease has been serious in the State for several years. New Zealand spinach was found to be 100 per cent resistant to the wilt and also to summer heat.

Sweet potato scurf or soil stain caused by *Monilochætes infuscans* has been studied at the Delaware and New Jersey stations. The former station found it could be fully controlled by disinfecting the seed with corrosive sublimate except in fields that had been cropped with sweet potatoes for a number of successive seasons. Infected seed that had not been treated produced heavily infected sprouts, with little possibility of normal growth. The disease was more prevalent where the humus content of the soil is largest. At the New Jersey stations good control was secured by broadcasting sulfur at the rate of 400 to 600 pounds per acre. Yellow Jersey and Nancy Hall were very susceptible and Red Brazil, Dahomey, Dooley, Pumpkin, and White Yam, resistant.

Study of sweet potato pox at the Delaware station failed to associate *Cytospora batata* with the disease. Infection seemed to occur in the field. Sulfur-treated plats gave an increase of 98.8 bushels over untreated plats, this treatment being most successful when inoculated sulfur was applied broadcast or drilled. Crop rotation is recommended to reduce the prevalence of the disease. The New Jersey stations also report that from 400 to 600 pounds of sulfur gave good control.

The soil rots of sweet potatoes were found by the Delaware station to occur in direct relation to soil temperature and moisture. When manure was applied, soil rot was more prevalent and it appeared that this, as well as plowing under a green cover crop, influenced the moisture content of the soil sufficiently to greatly increase the disease. Studies of stem rot caused by *Fusarium batata* and *F. hyperoxysporum* at the New Jersey stations showed that heavy applications of manure increased the disease. Seed selection gave no results, but treatment of infected potatoes with corrosive sublimate was important in preventing dissemination of the disease. It was worse on sandy loam soils. Dooley, Triumph, White Yam, Red Brazil, Dahomey, and Pumpkin appeared to be entirely or nearly immune.

In tests of sprays for the control of leaf blight and bacterial soft spot of the tomato at the Virginia station, good results were obtained both with Bordeaux mixture and soap-Bordeaux mixture, the latter being a little more effective. Copper-lime dust was not so effective as soap-Bordeaux spray in the control of leaf blight, but it greatly reduced loss of fruit from soft rot. At the New Jersey stations four or five applications of Bordeaux greatly reduced leaf spot caused by *Septoria lycopersici* and early blight caused by *Macrosporium solani*. Good results were secured with a dust consisting of 20 parts monohydrated copper sulfate and 80 parts of lime.

Studies of the strains of tomato and potato Phytophthora causing blight, at the West Virginia station, showed them to be distinctly biologic forms although closely related. It has been demonstrated by the Indiana station that tomato mosaic is carried over in the field by the perennial ground

cherry. When the growth of this plant was kept down, there was a 2 per cent infection as compared with 14 per cent in an uncleared field.

It was found at the Texas station that Fusarium wilt of tomatoes may penetrate to the interior of the seed. The fungus was isolated only from ripe fruit. Vines or roots which had been killed and dried for nearly four months still yielded virulent growths of the Fusarium fungus. At the Missouri station the capacity of the organism to produce infection was found to be greatly reduced or inhibited by increased acidity of the soil.

Flower diseases.—Snapdragon rust was controlled in a warm greenhouse at the New Hampshire station by sulphuring, but in the open the control was not good even though a temperature of 22° C. or above was maintained for at least four hours each day by moving the plants into the greenhouse. However, plants growing in the field were protected from the rust if they were covered by bell jars at night. At the New York State station Septoria leaf spot of China asters was found to be seedborne and was controlled by sterilizing the seed bed with corrosive sublimate.

Forest tree diseases.—The Connecticut State station found that it does not pay to cut out white pines affected with blister rust, as the disease is self-limited. Infection was found to be through the stomata of the leaves in the late fall. Inoculations in different species of pines showed that the disease will attack other 5-needle species. The fungus grows in the needles and works down to the stem the next season. Ribes appears to be a secondary host, and its eradication for a distance of 500 yards from a white pine stand is considered fairly safe. The disease is probably windborne from Ribes to pine and vice versa.

Cereal diseases.—In extensive studies of blight of cereals at the Wisconsin station, it was found that *Gibberella saubinetii* grew normally in pine cultures over a wide range of temperature, from 3° to 32° C. The optimum temperature for spore formation and germination was 24° to 28° C. Seedling blight of wheat developed on young plants at high soil temperatures and on corn at low soil temperatures. Lowering the soil moisture to a point where normal growth of the seedling was inhibited predisposed both wheat and corn to attack. Wheat seedlings grown with a low light intensity blighted badly; those with a high light intensity and a longer period of illumination did not blight. Chemical studies showed that at low temperatures wheat seedlings separated from the endosperm were high in sugars, but that corn seedlings were low in sugars. The dextrins or gums were also lowest at low temperatures. The relatively high content of available carbohydrates in the wheat seedlings at low soil temperatures and of corn seedlings at high soil temperatures was found to result in thickened cellulose walls, offering resistance to fungus penetration.

Thirty-eight biologic forms of rust, varying in virulence on different varieties, have been isolated and their distribution and methods of identification determined at the Minnesota station. Wheat infected with *Puccinia triticina* or *P. graminis tritici* showed lower water economy than normal wheat. The addition of sodium chloride or monosodium phosphate to a basic three-salt nutrient solution had no effect on susceptibility, sodium nitrate caused greater infection but increased the yield, calcium chloride and magnesium chloride appeared to reduce susceptibility, and calcium chloride reduced the water requirement. The Idaho station found *Puccinia glumarum* on 59 species of wild grasses, as well as on wheat, barley, rye, spelt, and emmer. *P. glumarum tritici* was found to overwinter in the uredineal stage on the Pacific coast and intermountain regions of the West, but not to be transmitted from one wheat crop to the next by infected seed. Cytological studies at the Minnesota station showed that the morphology of some wheats is such as to make it impossible for rust hyphæ to spread extensively within the tissue. Infection was traced in one case for a distance of 7 miles from a barberry hedge. Studies of wheat leaf rust at the Indiana station indicate a definite segregation and inheritance of resistance, and a promising start has been made in developing a resistant variety. There are several strains of the rust. Some progress has also been made in resistance to corn and rye leaf rust.

Copper carbonate was successfully used to control smut in wheat at the Virginia station, but was not so effective for oat smut as formaldehyde. At the Idaho station the highest percentage of infection of stinking smut of wheat occurred at a temperature of about 50° F. and a soil moisture content of about 22 per cent. There was a rapid decline of infection in moist

soil cultivated frequently. Copper carbonate proved a more effective treatment than bluestone. Nickel carbonate gave very good results. In a trial of a number of copper preparations for smut control at the Washington station, those with a low copper content were not so effective as the pure copper carbonates. The results indicate that 3 ounces of pure copper carbonate or 4 ounces of the weaker preparations should be used per bushel for fall seedings, and 2 to 3 ounces of the pure salt or 3 to 4 ounces of the weaker preparations for spring seedings, using heavier applications only when the seed is visibly smutted. Control of bunt with anhydrous copper sulphate was much poorer than with copper carbonate.

A study of two biologic forms of the fungus causing stem rust of wheat (*Puccinia graminis tritici*) at the Nebraska station showed that in no instance was the general type of infection changed on different wheat varieties by any environmental factors, including soil temperature and moisture and air temperature, by the source of inoculum, or by the source of seed of the host. The optimum temperature for the development of the disease was between 20° and 25° C. No infection occurred at 10° or below and only a few plants were infected at 15° or 30°. Studies of the viability of the uredospores under field conditions showed that they do not overwinter at the station. The highest germination and longest viable period of the spores was at low temperatures and medium relative humidity, and they died quickly with high temperature and humidity. Some evidence was obtained by the Colorado station that the uredospore stage can live over winter on stubble and wild grasses without the barberry being present. Germination of spores from rusted grasses kept over winter in plats was secured as late as April, indicating that under mild winter and good snow cover conditions the uredospores will winter over in Colorado as they do in Texas.

In a study of crown rust the Iowa station found that many wild and cultivated species of buckthorn (Rhamnus) may serve as hosts for the disease during part of its life history.

Marquis and durums as a group were found by the Minnesota station to be very susceptible to wheat scab; Preston, Haynes, Glyndon Fife, and several others are much more resistant. Results obtained at the Kansas station indicate that "take-all" is not spread by seed, but seems to be carried over chiefly in the soil. Continuous wheat shows the worst infection. Lime and gypsum appeared to increase infection, as did early plowing and disking fields.

Helminthosporium sativum was found by the Minnesota station to be widespread, causing many diseases and affecting all parts of the plant. It has many hosts and biologic forms and manifests itself in various ways. It overwinters in seeds and in plants in the field, and sporulates on dead and decaying plants. It is difficult to control, the development of resistant varieties being the most promising method.

Besides organisms previously reported, the Kentucky station found that a Helminthosporium was present in 25 to 50 per cent of the seed corn examined, a Macrosporium in a small per cent, and a Sclerotium in a few. All of the samples examined were found to be infected. Some seeds which appeared to be sterile when cultivated on plates showed infection on microscopic examination. It was found that by moistening the seed, placing it in a vacuum tube, and pumping out the air, the seed coat layers were pressed together, sealing the organisms between the layers, and the seeds could not then transmit the disease. At the New Jersey stations *Fusarium moniliforme* and *Cephalosporium* sp. were the most active organisms found, and *Gibberella saubinetii* also was common. The disease was considerably reduced by seed selection. Alkaline soils were found to be favorable to the disease. Flinty types of corn were found to be most resistant. The only organism found in this disease at the Ohio station was *Diplodia zeæ*, but cross-inoculations with this organism secured from ear rot did not produce a typical root rot. On undrained soil there was less difference in yield between diseased and disease-free seed than on drained soil. No relation was found at the Delaware station between the flora of cornsick soils and the cause of root rot, the flora being practically the same as that of nonsick soils. *Fusarium moniliforme* was found in some seed but was more or less inactive. *Gibberella saubinetii* was very active, as was *Diplodia zeæ*. The fungus reported from India as *Cephalosporium sacchari* was found by the Indiana station to be a Fusarium, but a nonpathogenic Cephalosporium was found. Attempts to reproduce the disease with

the organisms commonly associated with it, *Fusarium moniliforme* and *Gibberella saubinetii*, were not successful in soils that were high in nitrates. The rots were found to be most abundant in acid soils. Potash and phosphate prevented the invasion of iron by stimulating growth. Iron concentrates in the phloem tissue were found to precipitate the protoplasm, the cells breaking down. The effect of aluminum was nearly the same as iron, but it was more generally distributed through the plant. Phosphorus controlled aluminum injuries. Corn grown in an acid soil, with much available iron, often blackened when canned. Corn withstood an acidity of 3.5 when no available iron or aluminum was present. Calcium made potash unavailable, and as potash prevents nodal accumulation of iron, corn should not be too heavily limed. Susceptibility to root rot and the various strains of Diplodia and rusts is inherited. The absorption capacity of different inbred strains of yellow dent corn was found to vary widely, as reflected in the ash analysis, ranging in phosphorus absorption from 0.39 to 1 per cent of the dry matter, in iron from 0.026 to 0.063 per cent, and in potassium from 0.47 to 5.59 per cent (as oxides).

The optimum temperature for the development of ear rot of corn was found by the Iowa station to be 30° C. The disease gains entrance by nodal infection, not through the roots. The fungus of dry rot of corn (*Diplodia zeæ*) may attack the plant through the silk and ear tips; but the nodes of the stalk, the ear shanks, and butts of the ears are the chief points of attack. The fungus may spread in seed corn while curing or in corn cribs during damp weather. High temperatures favored the spread. Planting infected seed resulted in a decreased stand and lower yield. Infected seed were difficult to detect, except by germination tests. Long rotation, early field selection of seed, and germination tests appear to be the most practical means of control. It was found that the spores of corn smut germinated best at a high temperature, about 30° C., and on solid medium.

Untreated corn seed was found by the Tennessee station to be 100 per cent infected with *Fusarium* sp. Presoaking the seed, followed by a brief immersion in hot water and corrosive sublimate solution, gave 97.5 per cent clean plants.

Early plantings gave best results at the Illinois station with good disease-free seed, but with diseased seed later plantings were better. Diplodia was worse in early plantings if there was much moisture.

Cotton diseases.—In studies on the effect of alkali on resistance of Pima Egyptian cotton to blackarm or angular leaf spot, at the Arizona station, it was found that infection lasted over in the seed but not in the stalks left standing in the field. Seed treatment with sulfuric acid gave excellent results. Plants on alkali soils were more woody and hence less susceptible to injury by blackarm. Seeds soaked in cultures of the organism gave only about 3 per cent of infection in alkali soils, as compared with 30 per cent in alkali-free soils. Wild cotton is found to be susceptible to blackarm.

Cotton root rot has been shown by the Texas station to be due to a Phymatotrichum. The fruiting stage of the organism was secured in pure cultures. The disease appears to be carried over on a living host, there being no evidence that it is carried in the soil. In crop rotation it was carried by certain weeds. Cotton was found to be a very important factor in carrying the organism over winter, and underground infection was active during the winter months. Early planted cotton showed a far greater percentage of root rot than late planted. Perennial susceptible weeds, as the morning glory, help to hibernate the organism. A 2-year clean fallow did not absolutely eradicate all perennial weed carriers. The disease does not spread except by contact of roots. Cereal crops are immune, but outbreaks have followed corn in the cockleburs and tie-vines which grow between the rows. The disease is greatly reduced in a dry year. Very little difference in resistance was found between different cotton varieties.

Flax diseases.—Studies with *Fusarium lini* at the Minnesota station showed that this will grow with alcohol as the sole source of energy until it produces about 4 per cent in the medium and then it ceases to grow because of the toxicity of the alcohol. It ferments pentoses as well as hexoses but with relatively less alcohol formation.

Potato diseases.—Investigations at the Nebraska station on the viability of the causal organism (*Bacillus phytophthorus*) of blackleg under various conditions of temperature and moisture showed it to be very susceptible to desiccation. At 100 per cent humidity it remained viable for at least eight days. At 90 per cent humidity, with a temperature of 25° C., it re-

mained viable for only three hours. At 80 per cent humidity, with the same temperature, it lived for one hour only. Inoculation experiments on tubers showed that at the optimum temperature no rotting occurred at a humidity of 40 per cent or lower. Tests at the Montana station showed that five minutes' treatment of the cut seed with formaldehyde and corrosive sublimate solutions was sufficient to kill the organism, and this had no injurious effect on the germination of the seed.

Complete control of early blight on the late crop of potatoes was secured with Bordeaux at the New Jersey stations, only 0.5 per cent of the leaves on the treated plats being dead, compared with 57 per cent in the untreated plats. Spraying gave an increase of 69 bushels per acre, but copper-lime dust gave no increase. In studies on the control of late blight at the Florida station, copper-lime dust containing 6 per cent of metallic copper resulted in an increase in yield of 25 per cent over untreated plats. Bordeaux paste gave approximately the same results but was more expensive, but homemade Bordeaux gave as good control and was cheaper than copper-lime dust.

Stem canker was found by the Wisconsin station to be stimulated to its greatest development by low temperature, and with the organism present in the seed tubers the young shoots may be wholly destroyed or form weak plants. With higher temperatures the shoots escaped injury, and therefore early plantings, while the soil is cool, may suffer more than late plantings.

Studies on potato leaf roll at the Indiana station showed that if a disease-free hill became infected during the current season the yield was not reduced, but seed from this hill planted next year gave a decided reduction. The disease can not be accurately identified the first year in the field, and in selecting high-yielding hills these may be infected. The Vermont station has demonstrated that there is a physiological tipburn distinct from leafhopper tipburn. The physiological disease begins at the tip and margins of the leaf, while hopperburn may appear anywhere on the leaf.

Studies on potato scab at the New Jersey stations showed good control on lighter soils by the application of 300 pounds of sulfur, which was as efficient as 600 pounds and the residual effects in increasing soil acidity were less marked. Broadcast applications just before planting gave the best results. Too much sulfur produced harmful effects, but in heavy soils it may be used up to 500 pounds, depending on the amount of infection. Sodium nitrate in a complete fertilizer was found to increase the disease, and ammonium sulphate to decrease it. On the nitrate plats 62 per cent of the crop was unsalable, and on the sulfate plats 21 per cent. Soil moisture was shown to be an important factor, scab being most abundant on soils of low moisture content, and decreases in severity with increase in moisture. On soils with the same moisture content it was less severe on soils with a low hydrogen-ion concentration. Treated seed gave a 77 per cent clean crop, untreated seed 56 per cent, and treated seed on treated soil gave 93.9 per cent clean tubers. The Vermont station found the organism causing scab in virgin soil. The Wisconsin station found that high temperatures facilitated development of the disease, and that low temperatures lessened it.

In a study of potato wilt and stem end rot caused by *Fusarium eumartii*, the Nebraska station found that infection occurred chiefly from the soil rather than through the seed, but that infected seed produced weak plants more susceptible to infection from the soil. The organism produced a toxic substance, evidently pectinase, capable of killing the host in advance of the organism. The optimum temperature for the disease was 20° to 24° C. One form of wilt was caused by *Fusarium oxysporum*, different strains of which were found to vary as much as 5° in optimum temperature for growth. The potato was found to be most susceptible to infection during its early stages. Temperatures of 18° and below, as well as constant low moisture, were unfavorable to the disease. Vascular discoloration of tuber was observed in the absence of any organism. Verticillium wilt of the potato was found by the Oregon station to spread from plant to plant underground during the growing season. The removal of plants as soon as they showed signs of wilt tended to check the spread somewhat, but it was better not only to remove the affected plants but also the plants on both sides in the row. A 4-year rotation appeared to be effective in controlling the disease. Infection occurred through the roots and was found deep in the soil. Storage rots were found by the Montana station to be due in the majority of cases to *Fusarium trichothecioides*

and *F. solani*, and field wilt is usually caused by *F. oxysporum* var. *sclerotium*.

Seed treatment for Rhizoctonia infection of potatoes with the standard corrosive sublimate solution gave excellent results at the Washington station, and seed selection produced as good results as treatment of infected stock. Copper carbonate dust gave no control. Studies at the Utah station showed the danger of accumulation of the fungus in the soil when planted successive years with infected seed.

Potato mosaic was apparently completely eliminated at the Kentucky station in two seasons from seed stock which at the beginning was infected in varying amounts up to 95 per cent, by taking a single seed piece from each tuber and planting in early April, the remainder of the tuber being numbered and placed in cold storage for late summer planting. All plants showing signs of mosaic were noted and the corresponding tuber eliminated. No mosaic appeared in the tubers thus selected. On repeating this the second year, the crop was free from the disease. The Utah station distinguishes two distinct types of mosaic, one characterized by definite mottling with little or no dwarfing and one by prominent mottling, crinkling, and serious dwarfing. The New York Cornell station found a new host for potato mosaic in *Nicandra physalodes*, the apple of Peru. Tobacco mosaic is not transmitted to this plant. Neither hot air nor hot water treatment was successful in controlling mosaic or leaf roll of the potato. Observations at the Nebraska station showed that mosaic symptoms were masked at temperatures above 70° F. and were increasingly evident as the temperature dropped, but the effect of temperature decreased with the age of the plant and the severity of the disease. High sunlight intensities and low moisture were also correlated with the masking of symptoms.

Studies of the degenerative diseases of the potato, at the Maine station, of which there are at least seven, including leaf roll, streak, curly dwarf, spindle sprout, and mosaic, of which three distinct types have been found, showed that these can be disseminated by tuber grafts, stem grafts, leaf mutilation, rubbing in the juice of infected plants, and by at least two species of aphids. These diseases of the potato do not seem to be so contagious as the mosaic of tobacco, cucumbers, or tomatoes. The same disease does not act in the same way on different varieties of potatoes. Curly dwarf and spindle tuber are the only ones that can be detected in the tuber and these only after the first year. Hill selection did not help in improving the crop, as apparently healthy hills showed the disease next year. A distance of 200 feet from an infected field was not found to be safe for a new field to be planted, and in one case 700 feet was not enough. Aphids appear to be the principal means of transmission of the disease. There may be other insects that transmit the disease, but they have not been observed. The potato plant appears to get more resistant as it gets older. The Nebraska station found a type of degeneracy very similar to or identical with spindling tuber to be present in the State, manifesting itself by a stiff upright habit of growth and an elongation of the tubers. Strains affected by it never recover, but become progressively weaker. It is perpetuated through the tubers and appears to be transmitted from plant to plant in the field. Irrigation produces conditions more conducive to the rapid increase of this degeneracy than dry-land culture.

Evidence has been secured at the Maryland station that spindling sprout and other degenerative conditions are due to lack of some unknown growth-promoting substance.

A new disease, which has been named "spindle tuber" and which reduces the yield 50 per cent in some cases, was reported by the New Jersey stations. It is transmitted by aphids and there is no evidence that it is carried over in the soil. It is an infectious disease, but the organism has not been found. Transmission was secured by grafting in the greenhouse. Infected plants grow upright with smaller and more pointed leaves than healthy plants. The tubers are long, narrow, smooth skinned, and have more eyes than nominal potatoes, these sometimes being borne on knotlike protuberances. The shape of the tubers suggests the name. Good control can be secured by roguing, if this is done early.

In seed treatment studies at the Idaho station it was found that sprinkling the tubers with water and covering for 24 to 48 hours before treatment with either corrosive sublimate or formaldehyde increased the effectiveness of these treatments.

Tobacco diseases.—Observations made at the Kentucky station have led to the belief that seed beds are often infected with angular leaf spot by

laborers chewing infected tobacco and expectorating in the seed bed.

The causal organism of blackshank was found by the Florida station to be *Phytophthora nicotianæ*. Progress has been made in developing a resistant strain.

Tobacco mosaic was found by the Kentucky station to be carried over winter in the root stocks of the bull nettle and several other species of ground cherry common in Kentucky. It was successfully transferred from these to tobacco and the tomato. Mosaic of the bean, red clover, soybean, and pokeweed, and leaf roll of the potato could not be transmitted to tobacco.

A survey of the Burley section of the State by the Kentucky station showed that about 60 per cent of the plantings were damaged by root rot. A resistant strain developed by the station is now being planted. The Wisconsin station found that a low temperature favors this disease.

The organism causing tobacco wildfire, according to the Massachusetts station, readily overwinters on seed from infected pods. It may also overwinter on wood out of doors. The disease has been found on plants that were originally disease-free, set out in infected soil, indicating overwintering in the soil. Incorporating macerated infected leaves in the soil and overwintering these produced the disease. Sterile and unsterilized soils were inoculated, overwintered, and planted. The sterile inoculated soil gave infection but not the unsterilized soil, indicating perhaps some natural protection. There was no evidence that infected leaves plowed under are a source of infection. Control was best secured in the seed bed by frequent spraying with copper fungicides. Selection for resistant strains is offering some promise. Studies on this disease at the Wisconsin station indicate that the organism lives over winter on or in cured tobacco leaves or refuse, other places of overwintering being of minor importance. It was found that about 100 other plants, including many vegetables and field crops, may become infected with the disease.

Root rot was found by the Massachusetts station to be the chief cause of tobacco sick soils, the rot growing on legumes used as cover crops. Thielavia appeared to grow best in alkaline soils. A lighter rot was noted on plats on which timothy had been grown. Other factors than organisms were found to play a part in making a soil "tobacco sick."

Alfalfa anthracnose.—The organism causing this disease was isolated by the Mississippi station, grown in pure cultures and found to be identical with *Colletotrichum trifolii* occurring on clover, and inoculation experiments showed that it could be readily transferred from one host to the other. No indications of biologic strains were found. No considerable resistance was found in any of the alfalfa strains tested. It was shown that when the seed was sterilized with corrosive sublimate solution, 1:1,000, for eight minutes, no disease was found and there was no injury to germination.

Soybean diseases.—Field tests at the Indiana station showed that soybean bacterial blight is introduced with the seed, and indicated that the bacteria persist over winter in the field, probably in the seed. Soybean mosaic was found to be seed borne. From 10 to 25 per cent of seed from infected plants carried the disease, which persisted for two years, and reduced the yield from 30 to 75 per cent, but did not reduce the germinability of the seed. No other host was found. Attempts to transmit the disease by means of leafhoppers and tarnished plant bugs were unsuccessful. It was eliminated by field selection of seed.

Sunflower diseases.—There was found to be very little correlation between the amount of rust developing on sunflowers and the kind of fertilizer applied, in investigations carried on at the Minnesota station. Neither spraying nor dusting with copper fungicides controlled the rust appreciably. The perfect stage of the organism causing sunflower wilt was secured at the Montana station in the greenhouse on plants brought in from the field. Several different strains of the organism were found. Seed treatment gave negative results.

Chlorosis.—Chlorosis is not a specific entity, according to the New Mexico station, there being always found a deficiency in one or more soil constituents when it occurs. The use of ferrous sulphate as a spray or by boring into the trunk was only a temporary expedient and often resulted in poisoning the tree.

Mosaic hosts.—Twenty different families of plants have been found to be subject to mosaic at the Iowa station. Cross-inoculation experiments show that it is transmissible between plants belonging to different families and may be so transmitted by insects. Plants found affected with the disease not previously reported in the State include zinnia, callendula, celery, red

raspberries, *Aquilegia cœrulea*, *Stokesia* sp., *Euphorbia preslei*, *Vernonia fasciculata*, *Verbena urticæfolia*, *Lactuca scariola*, and *Abutilon theophrasti*. Cross-inoculation experiments at the Wisconsin station were successful with cucurbit mosaic in case of nearly all species of Cucurbitaceæ except watermelons, and also Martynia, pepper, milkweed, pokeweed, green seed citron, tobacco (through pepper), potato (through cucumber), pigweed, and cultivated wild cherry.

Environmental influences.—Seedling blight of wheat and corn, due to *Gibberella saubinetii*, was found by the Wisconsin station to be dependent largely upon environmental conditions, especially temperature, the most favorable with wheat being from 12 to 28° C. and with corn from 8 to 20°. The organisms functioned at temperatures from 3 to 32°. The critical soil temperature for blight of wheat was about 12°, and for corn 20 to 24°. Late seeding reduced the disease. In Helminthosporium infection temperatures at and above 24° and a high soil moisture were found to favor infection of wheat and barley seedlings. Studies on Ustilago infection showed that high soil temperature reduced infection of oats, and when combined with a high soil moisture the fungus was practically eliminated. The minimum temperature for the germination of spores of *U. avenæ* was 4 to 5°, the optimum from 15 to 28°, and the maximum from 31 to 54°. The most favorable moisture content was 30 per cent. The spores did not germinate in an oxygen-free atmosphere. For *U. zeæ* the optimum temperature was 20 to 34° and the maximum from 36 to 38°.

Phytophthora terrestria, which has been assumed to be the same as *P. parasitica*, was found by the West Virginia station to be a separate and distinct organism, *P. capsici* having no relation to either of the two. Seven species tested did not need to be deprived of food to reproduce. Maximum reproduction was obtained in some cases where potassium or sodium carbonate was supplied.

A study of the physiology of *Sclerotium rolfsii* at the Georgia station showed it to be acid-loving, growing well in beef broth of an acid reaction but ceasing to grow when this was made alkaline.

Toxic action of copper.—Uredinales were found by the New Hampshire station to be twice as resistant to the toxic action of copper as are other fungi. Uredineospores of these fungi were three times as resistant to copper as are æceospores. The conidia of *Venturea inæqualis* were more sensitive to copper than any other of the fungus spores studied. Burgundy mixture was more toxic to the spores of *Alternaria solani* than was Bordeaux mixture.

ENTOMOLOGY

Field crop insects.—For control of the alfalfa weevil, the Idaho station found liquid arsenical sprays to be more effective than dusts. The parasite *Bathyplectes curculionis*, introduced in 1921, has become established. The Nevada station also reports that the introduction of this parasite has been successful and that it is now spread over a wide area. It is believed it will be helpful in holding the weevil in check. Life history studies of the weevil indicate that it will probably be necessary to spray twice during the growth of the first crop for its control.

The optimum date for planting corn to avoid injury by the earworm was found by the Kansas station to be May 4 for all varieties except Hildreth. The white varieties appear to be more resistant to the insect than the yellow varieties. Spraying was found to be more rapid and effective than dusting in the control of this insect by the West Virginia station. It is only necessary to make the application to the ear and silk. A combination of lead arsenate and nicotine sulphate was successful.

Studies of the European corn borer at the New Hampshire station, under conditions at Durham, showed that pupation of overwintering larvæ began May 11 and continued until the end of July. The pupal stage for males was about 20 days and for females 18 days. Emergence of adult moths from overwintering larvæ began June 2 and continued until the middle of August. The average life of the female moths from the overwintering generation was about 18 days and of the male moths about 17 days. The average number of eggs laid per moth was 451 and the maximum number laid by a single individual was 1,003. The length of the egg stage varied from 9 to 12 days. At Durham the borer can complete two generations a year. It is spreading in the State at the rate of 20 to 25 miles a season. Being a flying insect, quarantine seems to be of little value. The Ohio station found this insect extending about 35 miles into the State

and advancing about 6 miles a year. There are no indications of a second brood in the State.

Corn root worms were effectively controlled by rotations, in experiments at the North Carolina station. Numbers of root worms were found in the spring on the roots of volunteer oats at the Louisiana station, suggesting that injury to corn may be caused by larvæ that are present on the roots of grasses when the land is prepared for corn, the larvæ coming from eggs deposited before the corn is planted. Corn planted on land that had previously been in grass was more apt to be injured.

Studies on the black corn weevil at the North Carolina station indicated that early planted corn is likely to be more infested than late planted, and may thus serve as partial protection to later plantings. Seed bins, if not thoroughly cleaned, promoted infestation of new corn stored in them.

In field tests on the boll weevil at the South Carolina station calcium arsenate was very efficient, especially when applied during the middle and latter part of the summer. In the fall of 1922, 95 per cent of the weevils collected at the Mississippi station were parasitized. At the Oklahoma station, of 500 live boll weevils placed in cages in various places in the cotton section just before a killing frost 34 survived in one locality but only 1 or 2 in others. At the Texas station emergence from hibernation began the last week in February and by April 30 it was 69.5 per cent completed. The last emergence was July 13, though 99 per cent had emerged by June 3.

The adult cotton square borer, a small grayish-blue butterfly, was found by the Texas station to deposit its eggs singly on the leaves, stems, or blossoms of the cotton plant. These hatched in 2 or 3 days and the worms immediately began to feed, becoming full grown in 12 to 16 days, when they went into the chrysalis stage, which lasted from 8 to 10 days. It also fed upon the Lima bean, cowpea, and various other plants. In early June the insects were abundant on cotton, but the June and July generations were heavily parasitized. Dusting with calcium arsenate gave good control.

Sugar-cane moth borer larvæ were found by the Louisiana station feeding on the following grasses, more especially during the fall and winter months: *Panicum barbinode*, *P. gymnocarpon*, *P. dichotomiflorum*, *Paspalum larranagæ*, *Holcus halepensis*, *Andropogon glomeratus*, and volunteer rice. Soaking seed cane in water at 50° C. for 20 minutes was effective in controlling both the case borer and mealybug, and the cane was not harmed unless the eyes were soft and ready to sprout. Temperatures lower than 50° were not effective in destroying the mealybug.

Orchard fruit insects.—Five and 8 per cent solutions of pine tar oils were found by the Maryland station to kill the woolly aphis on apple trees and to repel ants. Solutions stronger than 8 per cent were injurious to the tree. Two applications per year of an 8 per cent solution gave the best control with minimum injury to the tree, but a repetition of this annually for three years caused a considerable amount of injury. At the Virginia station spraying small apple trees in May proved most effective for the control of woolly aphis passing from elms to apples. Materials tested for the control of apple aphids at the West Virginia station, including dormant strength lime-sulfur, nicotine sulfate, miscible oils, and combinations of these, did not differ much in effectiveness. At the Maine station the green apple aphis was found to have many hosts not previously noted, including 24 botanic families.

The apple leaf roller was shown by the New York State station to be very resistant to common spray materials, the benefits derived from oil sprays being small, considering the cost. The preblossom and calyx applications were most beneficial. Late applications of spray or dust, preferably about the last week in August, were found by the Pennsylvania station to be necessary for the control of the leaf roller.

Life history studies of the apple maggot at the New Hampshire station showed two full broods in the State. In transfer tests the one-brood strains taken from New York to Massachusetts remained one brood, and the two-brood strains taken from Massachusetts to New York remained two brood. Crosses of the one-brood and two-brood strains gave progeny with two broods. Surface treatment with tobacco dust and lime was successful in control, sprays not being so efficient. The disposal of all dropped fruit, especially early apples, is recommended.

The pear psylla was satisfactorily controlled at the New York State station by all dust preparations containing nicotine, provided a sufficient amount was applied per tree.

Experiments with the peach and prune borer at the Oregon station showed that paradichlorbenzene was not effective with the western borer, which works higher up in the tree than the eastern form. Naphthalene whitewash gave good results when used late in the fall to catch the adults, followed by calcium cyanide in the spring.

The camphor scale was found to be widely disseminated in citrus trees, by the Alabama station. To control them, dormant oil spray should be applied immediately after the fruit is gathered, followed by a second application some time before spring. Light applications of heavy oils have given better results than light oils heavily applied.

Small-fruit insects.—Treatments with nicotine, soap, and water gave excellent control of the blackberry psyllid at the New Jersey stations.

Life history studies of the raspberry fruit worm at the Connecticut State station showed that this insect reaches the adult beetle stage in the fall, and winters as an adult. At the New York State station the following insects were found to act as carriers of raspberry mosaic: *Aphis rubi* and *A. rubiphila*, and the grape and apple leafhoppers.

The currant aphis was found by the New York State station to be susceptible to nicotine sulfate and soap sprays of standard strengths, as well as to dusting with sulfur-lead arsenate mixtures containing 1 or 2 per cent of nicotine. Superfine tobacco dust was also efficient.

The strawberry weevil was shown by the Tennessee station to hibernate in the woods and new plantings to be about as badly infested as old ones. Where serious infestation occurred, early poisoning was necessary. It was found that true sexual differentiation in the strawberry root louse did not usually appear until late in the fall. Exposing infested strawberry plants to 7.5 hours' daylight, beginning February 23, resulted in the appearance of the sex stages of the insect by May 7, and eggs were laid by May 22. Ordinarily this does not occur until well into November. The strawberry crown borer was found to be wingless and to migrate very slowly, so that new plantings with runners can be safely made within 100 yards of old ones; and this, with rotation of crops, will reduce the injury to a negligible one.

The cranberry girdler, according to the New Jersey stations, can be destroyed by summer flooding. Shallow flooding on sunny days did no damage, but deep flooding on dark days was injurious. At the Washington station excellent control of the cranberry fireworm was secured by spraying with nicotine sulfate, 1 part to 400 parts of water. The cranberry weevil was controlled by winter flooding. Where this was not possible sodium cyanide, 1 ounce to 15 gallons of water, 1 gallon to the square foot, was effective.

Vegetable insects.—The Alabama station found that the Mexican bean beetle produces two full generations each year, the life cycle requiring a minimum of about 30 days aside from the period of hibernation, which is about 200 days. It is rapidly spreading northward. It attacks all varieties of bush and pole beans, but Lima beans are somewhat less rapidly infested. Cowpeas are readily attacked and destroyed in the absence of more common food plants. Dusting with a mixture of calcium arsenate, sulphur, and hydrated lime in the proportion 1:1:4 is recommended. There was less burning when there was no dew on the plants and it is recommended that the dusting be done at intervals of 1 week to 10 days throughout the growing season. The Kentucky station found this insect for the first time in the State in June, in the southern part, but it has since spread northward and westward. Dusting with arsenate of lime and hydrated lime gave effective control.

Life history studies of the cabbage root maggot, at the Pennsylvania station, showed a first and partial second and third broods in eastern Pennsylvania. Two important parasites were reared from pupæ. The approximate time for the first treatment with corrosive sublimate for maggots on early cabbage is normally during the last week in April. At the New York State station, either corrosive sublimate or tobacco dust controlled the maggots effectively.

The striped cucumber beetle was more effectively controlled by calcium arsenate and gypsum than by nicotine dust in experiments at the Indiana station. The Missouri station reports that an effective way of repelling the beetles in a small garden is to press two or three naphthalene balls into the soil around each vine.

For the onion maggot fly, a poison bait of molasses and yeast with sodium arsenite proved to be very effective at the New Jersey stations. The bait also attracted the seed-corn maggot fly.

The green pea aphis is reported by the Michigan station to have invaded the State and to attack not only peas but also alfalfa. It is held somewhat in check by natural parasites, which include ladybirds, two species of hymenopterous parasites, one a Lysiphlebus, and a fungus disease, identified as *Empusa aphidis*. Observations at the Wisconsin station indicate that alsike clover, red clover, and alfalfa are usually the center of early infestation of the pea aphis in cultivated fields, and from these the aphis slowly spreads to adjoining pea fields early in June. A large number of natural enemies were noted, which may entirely control them.

Life history studies of the spinach aphis (*Myzus persicæ*) at the Pennsylvania station, showed that the average reproductive period in the insectary was 14.8 days, during which an average of 21.2 young were produced by each female. Nicotine sulfate, 40 per cent, at a dilution of 1:500, using soap as a spreader and activator, gave efficient control. Dusting experiments showed a higher cost than spraying, but the efficiency was about the same.

Efficient control of the squash vine borer was secured at the Massachusetts station with nicotine sulfate, 1:100, as a spray. It acted somewhat as an ovicide, but mostly as a larvicide. Four applications made one week apart during July, at the rate of 300 gallons to the acre for the four applications, are recommended.

Stored grain insects.—It was found at the New Jersey station that when finely ground clays were inclosed in the same chamber with common white beans, but kept from direct contact with them by absorbent cotton, the infestation of weevils was reduced. When the clay was mixed with shelled corn and wheat it protected these grains against later attacks by the Angoumois moth, and mixing with wheat already infested reduced the infestation. The clay appears to act mechanically and can be easily washed off. A mixture of chloropicrine and carbon tetrachloride for fumigating grain in elevators was found by the Minnesota station to combine the good qualities and largely to overcome the disadvantages of each.

Scale insects.—The most satisfactory control of the San José scale was secured at the New York State station with a lime-sulfur solution, 1:8, applied as a spray when the buds were opening. With incrusted conditions, however, the Indiana station failed to get effective results with either dry or liquid concentrated lime-sulfur. Miscible oils or lubricating oil emulsions, when applied as dormant sprays in the fall or before the leaves came out in the spring, gave 100 per cent control. Lubricating oil emulsion is recommended for average conditions, because of its lower cost. The Arkansas station found that a 2 per cent lubricating oil emulsion dormant spray controlled the scale and did not injure peach trees.

Winter spraying for the oyster-shell scale proved ineffective at the Indiana station, because the insect passes the winter in the egg state, but summer sprays applied soon after the young hatch were thoroughly efficient.

Aphids.—The Maine station found that the green aphid of the apple has a winter and a summer food plant but may pass both cycles on the apple, being the only aphid of the apple that can do this. By the transference of winged forms one or two generations were bred on a number of other plants. It was found that *Aphis gossypii* has a similar range, and it is suspected that the two may be the same. There were found to be structural differences of *A. pomi* on different host plants. It usually occurs as a yellow form on its summer food plants, but is sometimes green. *A. gossypii* was found on the cucumber in one locality.

The length of day was shown by the Tennessee station to be an important factor influencing the early or late production of migrating forms of aphids. The primary host of the woolly aphis was found to be the elm in Tennessee as it is in Maine. The stem mothers hatched on the elm as early as the latter part of February and settled down at the base of a bud. The continued sucking caused the bud to swell and form a rosette in which vast numbers of lice were produced. The first winged forms or spring migrants developed the first week in May. As many as 10 to 12 generations were produced on the apple and by September the fall migrants made their appearance and continued to appear as late as December 1.

A variable temperature was shown by the West Virginia station to produce a greater growth in aphids than a constant one furnishing the same amount of heat.

Several new species of aphids affecting conifers were found at the Colorado station, some of these being of economic importance. Some forms were heavily parasitized.

Grasshoppers and crickets.—The fatal high and low temperatures for grasshoppers were found by the Minnesota station to be 52 to 54° C. and —10 to —12° C. High humidity apparently lowered the fatal high temperature.

Broadcasting poison bait for the control of crickets was found by the South Dakota station to be most effective if done in the late afternoon, as the feeding time of the insect is from 4 to 6 p. m. Addition of amyl acetate to the bait was of no advantage. Two parasites were found which were capable of destroying 50 per cent of the eggs. Cultivation was also an effective means of destroying the eggs.

Mosquitoes.—Observations made at the New Jersey stations showed temperature to be the governing factor in the activity of the mosquito. It decreased below 60° F. and stopped at 50°. Above 60° it increased two or threefold for each 10° increase up to an optimum of 80° and then decreased to 100°, when it stopped. Activity increased with humidity below 75 per cent, was constant from 75 to 85 per cent, and decreased at from 85 to 95 per cent. High temperature and low humidity increased the attraction to human beings, but this was overcome by high humidity and precipitation.

The chinch bug.—Calcium cyanide was found by the Missouri station to be efficient in preventing chinch-bug migration. The most effective way of using it was to plow a deep furrow between the corn and wheat, throwing the dirt towards the corn, and at the bottom of the furrow placing a line of calcium cyanide flakes, 1 pound to every 60 feet, preferably in the early part of the afternoon. It was found necessary to renew the application practically every day and in some cases to maintain the barrier for about 10 days. Dusting with calcium cyanide in the field before the bugs began to eat gave good control. At the South Dakota station there was found to be one complete and one partial generation of this insect in the State annually, only the adults and a few nymphs of the partial second generation surviving the winter. Natural enemies controlled to some extent.

Leafhoppers.—In the leafhoppers causing curly leaf of sugar beets, the California station found six instars when temperatures were high. In the cultivated districts of the San José Valley there were found four broods from April to October and a winter brood in the foothills. In the Salinas Valley three broods were found and at Berkeley two. No evidence was found that curly leaf is transmitted by the mouth parts or by external mechanical carriers. The minimum incubation period in sugar beets with two or four leaves was two days, the period varying with the size of the beet, the older the beet the longer the period. The causative agent traveled from the leaf through the blade into the beet, progressing 7 inches in a half hour. The inner leaves showed symptoms first. The disease was not transmitted from beet to beet through the soil, but only by the hopper, and no other insect was found that could transmit it. Thirteen weeds have been found which harbor the disease.

Cutworms.—Cutworms were controlled by the New Mexico station by the use of London purple. Tests at the Montana station showed early spring plowing to be of value in controlling the pale western cutworm. At the North Dakota station the most serious injury from this insect was in case of crops following small grain, especially wheat. Eggs of the insect were found commonly in hoof tracks in such fields. Little or no damage followed cultivated crops, as corn and potatoes, or grain crops such as rye, late flax, or late sown millet. A field with an unbroken crust, without wheel or hoof tracks, in early September, was likely to be free from infection and damage the following year.

Miscellaneous.—Wireworms were found by the New Jersey stations to eat large quantities of arsenic without injury, and they were also not injured by eating grains of corn treated with acids, alkalis, and other poisonous organic and inorganic materials. They were, however, easily killed with carbon bisulfide gas.

The best control of the black fly was secured by the New Hampshire station by treating the streams where they occur with an oil emulsion. They were found to be capable of flight for some distance. Three species were found in the State.

The flower thrips, according to the Florida station, attacks practically all truck crops that bloom, as well as many wild plants. The Pee Dee variety of Spanish peanuts was especially subject to attack, particularly on the leaves. Satsuma oranges were severely infested. Dusting with a mixture of tobacco extract and dry lime-sulfur gave good control.

A nematode-resistant bunch variety of velvet beans is reported by the Florida station. By growing this crop for a single season the number of nematodes was reduced in truck crop

soils as much as is usually the case where resistant crops are grown for two or three years in succession.

In a study of millipede control at the Pennsylvania station, soil treatment for a foot along the backboard of fall-seeded coldframes protected the entire bed from losses in case of lettuce and carrots. Either sodium cyanide solution sprinkled over the soil 10 days before seeding at the rate of 150 pounds of cyanide per acre, or nicotine sulphate in water, 1:500, one day before seeding, is recommended. Favorable results were also obtained with a nicotine sulfate dust in a kaolin carrier at a rate of 2 per cent actual nicotine scattered in the open row at the time the seed was drilled.

Good control of red spiders was secured at the Pennsylvania station with all liquid forms of sulfur, but dusts gave poor or little control. Commercial brands of miscible oils in the dormant or delayed dormant period gave from 60 to 80 per cent kill of red-spider eggs. Lime-sulfur gave from 12 to 20 per cent kill.

Insecticides.—Gypsum was found by the Iowa station to be a good addition to dusts for the melon aphis and striped cucumber beetle, both of which were found to be carriers of mosaic and wilt.

Studies of spreaders and adhesives at the New Jersey stations showed one of the best and cheapest to be flour, with a 12.5 to 16 per cent gluten content, mixed with lead arsenate at such a rate as to give the mixture a 3 per cent gluten content. Gas evolution from nicotine dust was shown to occur mostly in the first three hours and was practically over in nine hours. There was little evolution of gas below 50° F.

The incorporation of spreaders with common arsenicals exerted no appreciable influence, favorable or otherwise, on their killing properties or rate of action, in experiments at the New York State station. Attempts to grow tobacco with a high nicotine content, for insecticidal purposes, showed that fertilizer treatments had little effect. Superfine tobacco dust, applied in lime-sulfur solution, gave satisfactory control of red bugs and the rosy aphis.

The efficiency of nicotine sulfate was found by the California station to be increased from 20 to 30 per cent by the addition of sufficient alkali to neutralize the combining acids. Tests with calcium cyanide dust for scale insects showed that if this was finely divided it gave off gas quickly and freely and did not injure the foliage unless rains came, when the leaves dropped. Low temperatures seemed to harden some insects or make the gas ineffective.

Pure soaps (sodium stearate or oleate) were found by the Montana station to dissolve lead from both mono- and diplumbic arsenate, the latter being more soluble than the former. The solvent action of the stearate was greater than that of the oleate. There appears to be little danger of burning foliage if only oleate soap is used.

Bees.—The Minnesota station found that bees can regulate the body temperature within limits. The average temperature of the bee's body was 4.7° C. above that of the surrounding air when this was 5.5°. It was the same as the air temperature when this was from 35° to 40° and was lower when the air temperature was 52° or above, if not exposed to the high temperature too long a time. The fatal maximum body temperature was found to be 46° to 48°. The freezing point was —1° C.

Colonies wintered without packing at the Wisconsin station required 31 pounds of stores from November 26 to April 12, compared with 9.75 pounds for colonies wintered in a heavy packing case. A colony exposed to 57° F. formed a compact cluster and maintained the temperature within it by muscular action, the warmest part of the cluster varying from 70° to 90°. The colder the outside temperature the higher the temperature maintained within the cluster. A study of the variation in the size and shape of queen cells at the Texas station showed that unusually small cells did not contain enough food to last the young queens to emergence and they were small and inferior. It was found that unusually large cells produced relatively larger queens.

FOODS AND HUMAN NUTRITION

Studies with rats, at the Illinois station, on an 8 to 10 per cent plane showed that the biologic value (which is the ratio of the total absorbed nitrogen to the nitrogen retained in the body) was highest with veal, being 85, and lowest with tankage, 33. Milk was very close to veal, with 83, wheat averaged 70, potatoes 63, and navy beans 38. With animals on a 5 per cent plane, the biologic values were veal 97, milk 94, potatoes 39, and navy beans 29.

To test the popular belief that a high protein diet is a renal irritant.

rats were fed on such a diet at the Connecticut State station, with a suitable supply of vitamins A and B and inorganic salts. It was noted that the kidneys were hypertrophied, but this was not of an inflammatory nature and was not accompanied by hypertrophy of the heart. The animals grew from 60 to 260 grams in weight, with but little subcutaneous fat and the skin was adherent.

At the California station rats receiving strawberry juice with a non-vitamin C basal ration, did well and reproduced, but did not thrive well with loganberry juice. Studies of raisins, dried raisin seed, and raisin-seed oil, at the Pennsylvania station, showed these materials to contain little if any vitamin A but vitamin B was present to an appreciable extent. Dried raisin seeds were not so rich in this as were raisins. It was not possible to demonstrate the presence of vitamin C in these materials.

Investigations on canned peas, at the Wisconsin station, showed them to be inferior in vitamin content to fresh peas which were cooked by steam and subsequently drled, although they were not entirely valueless as a source of vitamin B.

A close relation was found, by the New York State station, to exist between the moisture content and popping quality of pop corn. As the moisture content increased, the yield of popped corn increased to a maximum and then declined, as measured by volume. Corn stored outside popped better than that stored inside of storage rooms, on account of the moisture. Pop corn that did not germinate was still good to pop.

Studies on flour, at the Minnesota station, showed that no extracellular proteases are contributed to a dough in consequence of the inclusion of soured baker's yeast, and cleavage of the gluten is not affected by yeast to an extent that renders such changes a contributing factor in dough fermentation. Alkaline sodium phosphate produced more unfavorable effects upon the dough, due to alkaline residual salts, than did acid ingredients commonly used in baking powders and self-raising flours.

In studies of the nutritive value of milk, at the Vermont station, pigs were fed from 2 days old to weaning time, with a normal milk containing 3½ per cent protein, to which powdered protein was added, up to 10 per cent. The results showed that an addition of 2 per cent was the economical limit. Similarly, pigs were fed with milk containing 2, 3½, and 5 per cent of fat. Measured by the composition of the body at weaning time and the amount of gain, 2 per cent milk was the most economical. Data obtained at the Pennsylvania station indicated that pasteurization has no appreciable effect on the chemical and physical properties of the various milk constituents, and no nutritive difference was noted when fed to rats. Studies at the Minnesota station show that human milk is quite as adequate as cow's milk, as a source of vitamin A, for experimental animals, but is not adequate as a source of vitamin B in amounts which give good results with cow's milk.

Investigations on the preservation of eggs, at the Montana station, showed that at least two kinds of molds and a dozen species of bacteria frequently take part in egg spoilage. Of the various methods compared, immersion in water glass diluted 1 to 15, gave the best results and had an antiseptic action. Whatever preservative is used a relatively low temperature is best to preserve the natural flavor. The cost was a little less than 2 cents a dozen for materials and labor.

ANIMAL NUTRITION

Vitamins.—Experiments at the Iowa station with rats, rabbits, guinea pigs, and pigeons showed that vitamins in the ration are important in maintaining natural resistance to bacterial infection. Rats with a deficiency of vitamin B showed a marked susceptibility to anthrax and pneumonia. Vitamin deficient rats were also more susceptible to diphtheria toxin than normal animals. A marked drop in body temperature occurred, followed by subnormal phagocytic activity. Poor, weathered alfalfa hay was found to be poor in vitamins. Ordinary feeding rations were found to be very likely low in vitamins. The requirement for vitamin B appeared to be greater in chicks than in mammals. It was found at the Kansas station that chicks did well for a while without vitamin C, but if vitamin B was omitted the chicks developed beriberi. Cows responded to vitamins in the same manner as other animals, and although they got along for some time without vitamin C they ultimately succumbed. Bacteria producing vitamin B was found to occur in the paunch of the cow. Lack of vitamin A caused nervous disorders in pigs, with paralysis and poor vision, leading to blindness but no disorder of the eyeball, the results resembling blind staggers in horses. Hogs got along for a con-

siderable time on a limited amount of vitamin C (or green feed), but brood sows did not do so well. Pigs fed on a basal ration with no vitamin either died or were abnormal, but were cured with cod-liver oil.

In a comparison of milk and its preparations, at the Missouri station, unpasteurized whole milk gave the most uniform and most nearly normal growth of rats, while whole milk powder gave a very comparable growth curve. Skim milk gave practically the same rate of growth as whole milk for two months, when the rats became more susceptible to colds and reproduced but little. Evaporated milk gave low growth and low production, but the rats were healthy. Growth on filled milk was very low, the curve was nearly flat after 10 days, and there was no reproduction. Tests indicated that if vitamin B was deficient high protein (casein) afforded some protection.

With chicks fed a ration deficient in vitamin A, the Ohio station found a marked response with dried buttermilk, which seemed to supply something deficient in meat scraps. White clover gave as good results as butterfat. Cod-liver oil was not effective with a synthetic ration, but with normal food the results were good. With a synthetic ration the average weight of chicks receiving cod-liver oil was less than those receiving butterfat, but the percentage of lime in the bones was higher. The most practicable sources of vitamins required for the growth of chicks appeared to be green clover, alfalfa, cabbage, and grasses. Consistent results were obtained with rats, showing that these animals do not have the capacity of storing vitamin B.

The distribution of the antirachitic factor was found by the Wisconsin station to be very different from that of other vitamins. Attempts to extract this vitamin from hays by alcohol failed. Ordinary white light, as well as the light from a mercury vapor lamp, was found to supplement a ration low in antirachitic vitamin, producing an effect similar to that obtained when it is present. It seems possible that animal life is dependent for its mineral regulation more upon sunlight than upon food material. Rats were found to store fat-soluble vitamin in large amounts for future use, the liver being apparently an important center of such storage, the amount stored varying with the amount fed in the ration. Millets were found to be uniformly rich in fat-soluble vitamins, which bore no definite relation to the yellow pigment. Data were secured showing that cod-liver oil contains both vitamin A and antirachitic vitamin. Phosphorus in the blood appeared to be correlated with growth and may be an index of the need of antirachitic vitamin. Antirachitic vitamin was destroyed by fermentation, and germination appeared to activate the vitamin. This station also found the antirachitic vitamin of alfalfa hay to be destroyed by exposing it to the sunlight and weather, and assimilation of calcium in the body of animals receiving such hay was impeded. Although alfalfa hay cured in the ordinary manner was quite as high in lime content as that cured in the dark, its lime content was apparently completely unavailable. Hays dried in the sun but not exposed to the influence of moisture, as rain and dew, retained the antirachitic factor in greater abundance than those cured with exposure to all weather.

Preliminary studies at the Pennsylvania station indicated that vitamin B is not destroyed by any of the processes used in evaporating milk. Sweet cream butter, not overworked, was found to give the highest content of vitamin A.

Cooking cowpeas did not lower their vitamin value in experiments at the Arkansas station. The ground bean was rich in vitamin B but less so in vitamin A. The proteins were found to be very satisfactory, but the minerals were rather deficient. Tests with the whole mature plant showed that the proteins were not so good, vitamin B was very good, and vitamin A good, and the mineral matter was sufficient.

The vitamin B content of the entire egg yolk is not large, according to the Connecticut State station; and the whole egg is not exceptionally rich in vitamin B, as compared with many other foods. Experiments with rats showed that an average egg is equivalent to the vitamin B potency of about 150 cubic centimeters of cows' milk, or a quart of milk is about equivalent to six or seven whole eggs. Evidence points to the storage of vitamin in the body and not to its synthesis. Two lots of rats were fed, one with a normal diet and one with a diet deficient in water-soluble vitamin. Other rats were then fed on the livers of these. Those fed on the first lot responded quickly and did well, but those fed on the livers from the depleted lot did not. It was found that cod-liver oil, through which oxygen had been bubbled for a considerable

time while the fat was kept warm, lost its vitamin A potency and its capacity to cure ophthalmia, but the mere heating of a vitamin A-bearing product did not necessarily destroy its potency.

Experiments on the seasonal variation in the vitamin A and B content of milk, at the Minnesota station, showed that a milk rich in vitamin, particularly vitamin B, is not necessarily associated with a diet of pasture alone, although it is distinctly better in vitamin A. It is believed that cows on pasture should be fed a liberal grain ration in order to insure an optimum content of vitamin B in the milk. It was found that vitamin B in milk was not affected by either the spray or drum process of drying, but the vitamin A content of drum-dried milk seemed to more nearly approximate the original milk in this respect than did milk dried by the spray process. It was found necessary to heat milk to 180° F. for an hour in the presence of a stream of oxygen in order to destroy its antiscorbutic vitamin. The vitamin A content of butter showed a noticeable diminution when the butter was kept at a freezing temperature for nine months. Studies on the effect of vitamin B deficient diets on the growth and development of the organs of cockerels showed that the birds receiving such a diet suffered a decrease in size and weight of the organs in the following order: Testes, spleen, heart, liver, kidneys, pancreas, and thyroid, the testes being affected the most and the thyroid least. The animals increased in weight. A definite accelerating effect was noted, with vitamin B, on salivary amylase. Evidence was obtained that rats do well on diets free from carotinoids, confirming the conclusion that there is no chemical relation between carotin and vitamin.

Velvet beans were found by the Alabama station only slightly to benefit pigeons affected with polyneuritis from a polished rice feed; but, when fed the alcoholic extract of the beans, four out of six cases recovered. Rats did not thrive on any ration containing velvet beans. Velvet bean and pod meal was found by the Arkansas station to be rich in vitamin B, which, however, was mostly concentrated in the pod, while both the pod meal and beans were rich in vitamin A.

Chickens fed upon degerminated white corn developed leg weakness, which was cured by the addition of yeast, in experiments at the Indiana station.

Mineral nutrition.—A high degree of tolerance to acids in mineral metabolism without harmful effects was shown in experiments with swine at the Iowa station.

Green feeds helped calcium metabolism as lactation advanced, in experiments at the Ohio station, as a result of better digestion, and this appeared to be as much of a factor as the vitamins. Fineness of division appeared also to be a factor in assimilation. Goats fed colloidal phosphate stored calcium, but those receiving coarser phosphate did not.

A positive calcium and phosphorus balance was maintained in liberally milking cows, in experiments at the Wisconsin station, when dry alfalfa hay of good quality was used as the principal roughage, supplemented with corn silage and a grain ration. There was a greater storage of calcium when fresh green alfalfa was used. The results with hay depended upon its character as affected by curing. Negative calcium and phosphorus balances were obtained with rations of grains, corn, silage, and timothy hay. Substituting alfalfa hay or bone meal for the timothy hay did not restore the balance. With young rats, calcium lactate, carbonate, phosphate, silicate, and sulfate appeared to be equally assimilable. The larger the calcium intake the less the vitamin required for normal growth. Deficient calcium assimilation with abundant calcium intake was apparently not due to the form of the calcium but to deficiency of vitamin. Hay from a highly acid soil, the hay containing less than 0.5 per cent calcium oxid, inhibited reproduction. Cows fed rations containing plenty of protein but low in lime produced calves that were either dead at birth or so weak that they died shortly after. Cows fed a ration of timothy hay (containing only 0.73 per cent of calcium oxide), silage, and grain, compared with a lot receiving alfalfa hay, silage, and grain, were much slower in breeding and gave a rapid decrease in milk flow, and dried off earlier after being bred, indicating that a depletion of lime was probably taking place. There was apparently no difference in the effect of the type of calcium carrier used for the prevention of rickets, provided there was present an ample supply of antirachitic vitamin. Twenty cubic centimeters of cod-liver oil per week per animal was sufficient to protect against rickets. It was found that swine getting no dairy by-products, tankage, or green pasture were benefited by lime in the form of

steamed bone meal, wood ashes, ground limestone, or rock phosphate at the rate of 0.5 to 2 pounds per 100 pounds of grain or other concentrate. Lime appeared also to be needed when whey was used. Cows, sheep, and horses on forage from acid soils or on nonleguminous forage were benefited by lime at the rate of 3 to 4 pounds of the above mixture per 100 pounds of grain; and, even with legumes, bone meal or rock phosphate was used with advantage. Grains, wheat bran, and middlings being rich in phosphates did not require additions of this substance.

A wheat ration consisting of a constant amount of wheat, gluten, purified butterfat (vitamin A), calcium, and chlorine, with varying quantities of potassium, ranging from 0.03 to nearly 4 per cent, was fed to small animals at the Washington station. The rations containing the smaller quantities of potassium proved to be about sufficient for maintenance, whereas animals receiving larger proportions lost in weight and failed to reproduce. It appeared from experiments that potassium could not replace sodium, which is necessary whereas potassium is not. The amount of potassium in wheat is comparatively high. The variation of chlorine may be large in a wheat ration without greatly affecting growth and reproduction. A very small quantity of chlorine seems to promote growth and reproduction, and a large quantity does not seem to be detrimental. Neither wheat nor flour supplies a maintenance ration, but wheat can be made to by the addition of prepared butterfat, although still not adequate for growth and reproduction.

Velvet bean and pod meal was found by the Arkansas station to contain sufficient mineral salts for good growth, but the beans alone were deficient in minerals. All varieties of velvet beans were shown by the Alabama station to be low in ash and chlorine.

Larger amounts of manganese, copper, and zinc were found in the liver of animals than in other parts of the body, in studies at the Kentucky station. The copper content was higher in calves' liver than in that of more mature animals. Colostrum was found to be richer in manganese than milk produced later.

Protein.—The Nebraska station found that the skeleton was not influenced by increase of protein and an excess of protein tended to reduce the average daily gain in weight. A high protein ration was not found to be economical. The protein of velvet beans was found by the Arkansas station to be poor in amino acids and to give poor growth in pigs.

The proteins of corn meal and bran were found by the New York Cornell station to supplement each other and furnish a mixture of high quality. A combination of soybean oil meal and corn meal was found more efficient than corn meal alone.

Effect of sunlight.—At the Wisconsin station chickens fed a ration of white corn 60 parts, middlings 40 parts, salt 1 per cent, with skim milk to drink, died after four weeks unless kept in sunlight or given a small amount of raw egg (three eggs to 100 chicks). Feeding pork liver to hens produced better-hatching eggs and stronger chicks. Experiments with both poultry and calves, at the Kansas station, indicated that sunlight plays an important part in the development and metabolism.

Colostrum.—Calves fed pasteurized colostrum for the first three days and then put on cows' milk did as well as those on normal colostrum at the Missouri station. Of a group of 22 calves fed mixed milk from birth with no colostrum, 9 died and 13 were raised. White of egg in place of colostrum gave satisfactory results. Tests showed that guinea pigs do not need colostrum. Lambs were raised without colostrum, but pigs from which it was withheld died.

ANIMAL PRODUCTION

GENERAL

Influence of sires.—A study of blood lines of various classes of farm animals at the Virginia station indicated that breeds have been largely shaped and molded by the sires and that the future development of any breed depends to a very great extent upon its great sires.

Surface area of cattle.—An exact formula has been developed by the Missouri station for calculating the surface area of cattle, with an error of ± 5.5 per cent. This is $S = L.6 \times W.4 \times K$, where L is the length of the body in centimeters, the distance from the point of the withers to the end of the ischium or pin bone, W is the weight in kilograms, K a constant 217, and S the area in square centimeters.

Effect of arsenic on fecundity.—In experiments with rabbits at the Illinois station, with double simultaneous matings of different colored males to a single female, one male having re-

ceived Fowler's solution, the other not, 96 young were obtained, only 15 of which came from the treated and 81 from the untreated male. This seems to indicate that arsenic either decreases fertility or so weakens the spermatozoa that it decreases competition with sperm from untreated males.

BEEF CATTLE

Brahman-Hereford crosses.—Brahman-Hereford hybrids, at the Texas station, showed very little difference in susceptibility to the ox warble, but were apparently considerably less susceptible to horn flies. The first crosses were heavier than the Herefords.

Feeding.—In comparing oat straw, mixed hay, and corn stover, as a supplementary roughage to corn silage and cottonseed meal, at the Pennsylvania station, corn stover ranked first, oat straw second, and mixed hay third, from the standpoint of cheapness of ration, but mixed hay ranked first in maintaining the weight of the cows. Some of the cows getting oat straw or corn stover failed to breed regularly.

In experiments at the Montana station, younger cattle made more economical gains and slightly higher daily gains than older ones. The lighter cattle were in more favor with buyers.

In experiments at the Nebraska station with four groups of steers ranging in age from calves to 3-year-olds, the calves consumed much less feed than the older cattle and made much more economical gains. They likewise gained consistently throughout the period, whereas the older cattle gained rapidly at first and very slowly toward the close of the period. Heifer calves gained more slowly than steers and sold for a lower price.

Steers kept for a whole winter in a state of undernutrition at the New Hampshire station showed a capacity, with equal opportunity, to attain the same market finish as those wintered under normal conditions.

More profit was obtained at the Tennessee station from finishing winter-fed steers on grass than finishing during the winter period.

Steers fed on normal silage, at the Michigan station, made cheaper and larger daily gains, took on more finish, and sold at a higher price per pound than did steers fed on stover silage and corn.

Sunflower silage did not prove to be an economical winter feed for range calves at the Wyoming station. Native hay alone produced about one-third of a pound of gain per day and proved a sufficient winter feed for weanling calves. The addition of cottonseed meal, however, was a decided advantage.

Silage made from immature sunflowers was more palatable and gave better gains than that from more mature plants, at the Colorado station.

Experiments with corn, sunflower, sweet clover, sweet clover and oat straw, and millet silages, with 2-year-old steers, at the North Dakota station, showed that sweet-clover silage alone was more nutritious than sweet-clover and oat-straw silage, but was inferior to corn silage. Millet silage was less palatable than corn silage, as was sunflower silage, the latter being also distinctly inferior to it in nutritive value, but was superior to sweet-clover silage. Best sunflower silage was obtained from plants about 85 per cent in bloom.

SHEEP

Breeding.—Range ewes were bred to an average range buck, a crossbred buck, and a purebred buck, at the Nevada station. At the end of 180 days the lambs from the purebred sire weighed 12 pounds more than those from the range bucks, and 7 pounds more than those from the crossbreds, and the better-bred lambs gave a considerable increase in wool.

Short ears in ewes has been found by the New Hampshire station to be a Mendelian character, and the station has bred sheep in which this character is dominant.

Feeding.—Experiments at the Nevada station indicated that old range ewes can be brought through the winter on sunflower silage in such condition that they can lamb and mother their offspring. Sunflower silage has given as good results as corn silage for this purpose.

Investigations on lamb production at the Nevada station emphasized the importance of feeding ewes during the lambing period and putting lambs and ewes on the range in the best possible condition in order to bring the lambs through the summer in good condition. Lambs from better quality of bucks showed earlier maturity, better conformation, and improved wool. The advisability of carrying range lambs for a short feeding period on any available pasturage prior to shipment and the importance of alfalfa stubble pasture in this connection were also emphasized.

At the Iowa station shelled corn gave more satisfactory results than oats and barley fed with corn silage,

linseed-oil meal, clover hay, hominy feed, or gluten feed for fattening lambs. Beet molasses gave better results than cane molasses, but neither was equal to a corn ration.

In fattening lambs at the Oklahoma station unground kafir equaled ground. At the Kansas station whole kafir compared favorably with shelled corn. Grinding did not warrant the expense and threshing was of little advantage.

Almost the same gains were obtained at the Illinois station from a ration of shelled corn and alfalfa hay as from one of shelled corn and soybean hay, but it required 14 pounds more of corn and 93 pounds more of soybean hay than of shelled corn and alfalfa hay to produce 100 pounds gain. Lambs that received soybean straw as roughage required much more concentrates as well as roughage to produce 100 pounds gain than lambs fed alfalfa or soybean hay as roughage. Of the supplements used, ground soybeans were the least satisfactory. Both soybean-oil meal and linseed-oil meal produced slightly better gains than whole or ground soybeans.

Wool.—The New Hampshire station found that figures on tension and other characters of wool are only of value when taken under definite moisture and temperature conditions; length and diameter of fiber are more reliable.

The opinion generally held that the shoulder wool is always the finest on the sheep was found by the Wyoming station not to be true in all cases, especially with Hampshires, in which the middle of the side wool is slightly finer than the shoulder wool.

The average shrinkage on scouring was found by the Texas station to be 60.14 per cent with Rambouillet wool, 48.72 per cent with Corriedales, and 15.3 per cent for mohair. Shearing twice a year was found to be less profitable, when practiced over a series of years, than shearing once a year.

Goats.—Half-blood Toggenburg does, at the New Mexico station, produced 73.2 per cent more milk in their first lactation period than their native dams, and three-fourths bloods showed an average increase of 86.4 per cent over their granddams.

SWINE

Age and nutrition as factors in breeding.—Experimenting with sows, at the Missouri station, on three planes of nutrition from weaning time, those on a high plane came in heat first and those on a low plane last. The effect of the plane of the mother on the offspring was evident only up to the time of weaning and was due, evidently, to the fact that the low-plane mothers could not nourish their offspring as well as the high-plane mothers. Breeding as soon as pigs came in heat the first time has given no injurious effect on the progeny through 13 generations. Young pregnant sows continued to grow normally, gestation having no retarding effect; but, from the birth of the pigs, growth of the sow stopped for one or two months, becoming about normal as soon as the pigs were weaned. The younger-bred sows required from 12 to 15 months longer to reach normal mature size, and the offspring of very young sows required about 10 days more to reach 250 pounds. The type of hog was not injured by early breeding.

Market type.—In a comparison of compact, intermediate, and rangy types of Poland-China hogs, at the Illinois station, the intermediate type produced 3.6 per cent more rapid gains than the compact type, and 15 per cent more than the rangy type. The compact type required 3 per cent more feed and the rangy type 8 per cent more than the intermediate type to produce 100 pounds of gain. The carcasses of the compact type contained 6 per cent more fat and those of the rangy type 6 per cent less fat, than those of the intermediate type, and this type dressed better.

Feeding.—In a comparison of alfalfa and grain for brood sows, at the Delaware station, the alfalfa lot made the largest and the cheapest gains.

Excellent results were obtained with corn as the only grain for brood sows at the Wisconsin station, if this was properly supplemented and was strictly limited to the amount needed to keep the sows in a thrifty condition without becoming too fat. A ration of legume hay and grain was satisfactory. The addition of roots to the ration did not result in larger or more thrifty pigs, and was uneconomical under Corn-Belt conditions. No advantage resulted from adding a mineral supplement, such as steamed bone meal or ground limestone, to an efficient and well-balanced ration which included tankage.

Young pigs put on full feed after being fed for long periods on a maintenance ration were found by the Utah station to grow more rapidly and require less feed for a given increase than similar pigs put on the same feeds at once.

About 2.6 per cent less kafir was required per 100 pounds gain, in experiments at the Kansas station, when fed in the head than when threshed and fed whole; about 18:5 per cent less was required when fed threshed and ground than when fed in the head. Ground kafir was 35 per cent more effective than unground, in experiments at the Oklahoma station, the ground kafir more nearly equaling ground corn than did ground darso.

In a comparison of milo versus corn chops, with wheat straw, at the Texas station, pound for pound, milo was equal to corn; but when self-fed the pigs ate more corn and gained more.

Pigs 100 days old fed uncooked garbage from the university commons with barley, at the Wyoming station, made economical gains. Feeding potatoes alone gave poor results, better results being obtained when alfalfa, barley, and a mineral mixture were added.

In experiments at the North Carolina station, sweet potatoes were worth 34 cents per bushel, when fed alone, and 25 cents per bushel when fed with 2 per cent of corn. The pigs sold at a premium because of their excellent quality.

Soybeans planted in corn to be hogged down did not completely take the place of tankage in experiments at the Missouri station. Hogs on corn plus soybeans alone made more rapid gains and slightly more pork per acre than on corn alone; but since the amount of feed produced per acre with corn plus soybeans was usually no larger or even less than with corn alone, there was little more pork production per acre. Feeding tankage in a self-feeder to hogs on corn alone or on corn plus soybeans materially increased the rate and economy of gain.

Efforts to find a home-grown substitute for tankage at the Indiana station showed that soybeans may serve this purpose. When first fed they did not give as good gains as tankage; but it was found that by adding a mineral supplement they gave even better gains than corn and tankage, and the cost of gain was less. Supplementing corn with soybeans did not produce soft pork. The mineral mixture used was 1 part salt and 10 parts each of acid phosphate and wood ashes. There was less response with young pigs than with older ones.

A comparison of tankage, fish meal, peanut meal, and soybean meal at the Delaware station showed a decided advantage for the animal proteins in gains made, cost of gains, and finish.

Linseed meal or wheat middlings, as the only supplement to corn or barley for pigs not on pasture, gave poor results at the Wisconsin station, but better results with those on good pasture. Excellent results were secured with a mixture of equal parts of tankage and linseed meal when fed as a supplement to corn for pigs on good pasture, but this was not satisfactory for pigs on dry lot. For winter feeding a mixture of 50 pounds tankage, 25 pounds linseed meal, and 25 pounds chopped alfalfa proved very effective.

Ground barley, dry or soaked 12 hours, whole barley soaked 24 hours, and dry whole barley were compared at the Montana station with the result that grinding saved about 6 per cent of the feed and the gains were faster than with whole barley. It required 12 and 20 per cent more time, respectively, to finish the pigs fed the whole soaked barley and the whole dry barley than those fed ground barley.

Brood sows fed continuously on velvet beans, at the Alabama station, were deficient in milk production, and the pigs produced were below normal in weight and did not survive. Pigs fed rations rich in velvet beans for 180 days had bones of low specific gravity. The rations were not so efficient as those containing corn, shorts, and tankage. Older pigs ate and digested the beans more readily than younger ones. The iodine number of the fat of pigs fed velvet beans indicated soft pork. Velvet beans variously prepared and fed in varying quantities with corn and tankage did not give economical gains at the South Carolina station. The feed did not appear to be palatable. There was some indication that mature pigs made better use of the beans than younger ones. Pregnant sows fed velvet beans produced weak pigs which, however, survived.

The amount of high-priced tankage may be materially reduced, according to the Iowa station, by the use of good green pasture, such as alfalfa, clover, rape, and various other crops, the results being especially good with alfalfa. Tankage gave good results as a supplement to corn and alfalfa pasture at the Kansas station.

Commercial buttermilk feeds were not economical as compared with tankage or creamery buttermilk for pigs from 75 to 175 pounds weight, in experiments at the Minnesota station.

The Kentucky station found that spoiled buttermilk, even when putrid, did not injure pigs.

Pigs were stunted, in experiments at the Michigan station, by feeding yellow corn alone up to 5 months of age, and then divided into two lots weighing practically the same, one lot being then fed yellow corn and skim milk and the other yellow corn and a mineral mixture. At 12 months of age the pigs receiving the corn and mineral mixture weighed 76 pounds, while those receiving corn and skim milk weighed 335 pounds. At the Nebraska station, yellow corn and tankage gave better results than either white or mixed corn and tankage. The Iowa station found yellow corn better for growing and white corn better for fattening pigs.

Pigs on bluegrass pasture with a supplemental feed containing 20 per cent of tankage were supplied with various mineral supplement mixtures, in experiments at the Iowa station. The lot receiving no mineral supplements gained less and more slowly and required more feed per 100 pounds of gain than those receiving some form of mineral supplement. Similar results were obtained with pigs fed in the dry lot. The addition of powdered sulphur to a basal mineral mixture composed of salt, bone meal, ground limestone, wood ashes, and potassium iodide proved to be advantageous in that the gains were slightly increased and the feed requirement lessened. The Wisconsin station found that commercial mineral mixtures contain many useless ingredients, and advises the use of mixtures of bone meal, wood ashes, and ground phosphate. Mineral supplements were apparently not necessary for pigs on tankage or pasture. When marble dust, salt, and charcoal in equal amounts by weight were added to a ration of 2 parts corn and 1 part peanut meal, at the Alabama station, there was an increase in gain and in economy of feed, and the bones of the animals receiving the supplement were stronger than those not receiving it.

The age of pigs is an important factor in the production of soft pork, according to the Mississippi station, older pigs utilizing feed to much better advantage than young ones. Tests at the Georgia station showed that an excess of butterfat in the ration did not produce a soft body fat. When butterfat was fed for three months at the rate of 0.75 pound per day, the pork fat was firm and hard; the same quantity of peanut oil in the basal ration produced a somewhat softer fat. Hogging down corn with soybeans planted in the rows did not produce soft pork at the Kentucky station. At the Texas station, 140-pound pigs fed for 60 days on a ration containing 50 and 60 per cent of rice polish, with corn and tankage, did not produce carcasses sufficiently soft to require dockage. Several hogs receiving rice bran and one receiving rice polish were classed as slightly soft but were not docked. Rations containing 50 per cent of bran or polish produced greater gains and required less feed per unit of gain than those containing 60 per cent. Rice polish produced more gain per pound of feed than corn. Rice bran was more efficient in the fattening than in the growing ration. Paddy rice fed with tankage gave good results at the California station, the hulls giving no trouble. Rice bran and polish also gave good results, but the bran made the hogs rather soft while the polish caused them to scour.

Self-fed pigs, at the Texas station, reached a market weight at an earlier age than those hand fed. Self-feeding produced larger daily gains than hand feeding, but the amount of feed required to produce 100 pounds of gain was less in the case of the hand-fed lot.

POULTRY

Breeding.—As a result of very close inbreeding, at the Connecticut Storrs station, the hatchability of fertile eggs dropped nearly to zero in the third generation. The mortality of the 3-weeks old chicks increased from 3.6 to 24.7 per cent. The growth fell off rapidly in succeeding generations. The date of first egg (sexual maturity) increased from 220 days to 360 days in the sixth generation, and the average number of winter eggs fell off rapidly from 30 to 4. The egg size, however, did not go down and it is doubtful if the mature body size and weight did, for although inbreds were lighter at first they caught up in about two years, the size being measured by the bones.

By using males from pens having the highest percentage of fertility, the Montana station found an increase in hatchability in three years of 24.2 per cent. The amount of artificial light did not affect the hatchability of the eggs.

Organ transplantation.—Experiments at the Maine station showed that the presence of sperm or the antibodies to sperm did not apparently alter the ovaries or their functioning.

Egg production.—Eight years' data at the Indiana station show that pullets

maturing at 6 to 7½ months made higher average first-year records than those maturing earlier or later. Birds which laid before 8 months of age had a higher winter production than those beginning to lay later. Persistence of laying, or lateness in fall and winter, indicates a high producer. The number of eggs laid during the month of highest production is closely correlated with production.

The West Virginia station found that the younger the pullets when they began to lay the smaller were the first eggs. There was no correlation between early maturity and mean egg weight for the pullet year. The characteristics of the first four eggs laid in the pullet year tended to persist, especially the weight. Increased production was not necessarily at the expense of size of egg, but the more eggs laid in a particular period the smaller they tended to become. The mortality of progeny of fowls fed heavily for winter production was considerably greater than that for the progeny of those fed scantily during that time.

The North Dakota station found great variation in size of the first egg laid by individual pullets, from 1⅛ to 2 ounces, and that some individuals settle down to a normal-sized egg much younger than others, some never reaching a standard-sized egg.

The later the molting the higher the egg production, according to the Missouri station, except in the case of hens molting in October, which did not come back as well as those molting a month earlier. Hens molting after November 1 gave a much higher total egg production for two years than those molting before that date. A definite correlation between the date of starting molt and yearly production was found by the Iowa station, the high producers starting from October to December, the low producers any time after the first of June. The speed of molt also appeared to be correlated, high producers requiring about 100 days and low producers from 180 to 200 days. The wing molt appeared to be closely correlated with production. High producers laid more eggs while molting than low producers. Apparently the best layers tend to give a somewhat poorer hatching percentage than the poorer layers. With Leghorns, about the first of April was found to be the most advantageous date of hatching in relation to future egg production.

Experiments with a commercial yeast product, at the Pennsylvania station, indicated that pullets and hens not forced for egg production, and under conditions employing a good ration with adequate yards and runs, do not appear to need an additional amount of vitamin B supplied in the form of a yeast product to maintain their egg production and body weight. Hens and pullets ate more food as a rule and their body weights were somewhat more uniform when the yeast product was fed. It did not appear to be profitable to feed the yeast product except when pullets were forced to undergo a longer feeding and exercising period by the use of artificial light, under which conditions White Leghorn pullets were found to develop better and lay more and larger and heavier eggs.

Incubation.—The West Virginia station found the amount of carbon dioxide given off to be small until the middle of incubation, when increasingly large quantities of oxygen were taken in. The increase from the nineteenth to the twentieth day was practically equal to the total carbon dioxide given off during the first eight days and the increase from the twentieth to the twenty-first day was roughly equal to all that given off during the first half of the hatch. At the Missouri station, one lot of eggs held at 99° F. hatched. Below that, although there was considerable growth of embryo down to 94° F., none hatched.

Hatchability.—Normal-shaped eggs were found by the Masschusetts station to hatch best. The position of the embryo in the egg was not responsible for failure to hatch.

Deficiencies in either vitamin A or B in the ration were found by the Kansas station to result in extremely low hatching percentages, as did also the feeding of rations which did not include any green feed. The number of in-shell deaths was found to be greatest on the nineteenth day and 65 per cent occurred in the last week. No correlation was found between the weight of egg and in-shell deaths by the Connecticut Storrs station. The inheritance of in-shell deaths was found to be a simple character, as a rule, but in one case it was linked with a color character.

Effect of light.—The Nebraska station observed that chicks on a standard ration, which were exposed for an average of less than one hour daily to direct, unfiltered sunlight, developed normally, whereas chicks exposed to sunlight which had passed through common window glass devel-

oped rachitic symptoms. It is believed that the ultra-violet rays, which are filtered out when sunlight passes through window glass, are the active agents which influence calcium and phosphorus assimilation.

The increased winter production, with light, was much more pronounced with yearling hens, in experiments at the Kentucky station. Hens under light average 18 more eggs per bird during the four winter months than those without light. At the New Mexico station eggs produced under electric light did not give as high incubation, there being more dead-germ eggs.

Feeding.—The West Virginia station found that poorly fed chicks, which are stunted, never attain normal live weight even when afterwards fed normal rations. Egg production for the first season was reduced and the chicks were slower in reaching sexual maturity. At the Wisconsin station, chicks hatched from eggs from hens fed on a white corn and pork liver ration, as compared with those hatched from eggs from hens fed yellow corn and pork liver, died soon after hatching., and the hatchability was very low, indicating the necessity of vitamin-rich feed in the poultry ration. At the Kansas station, male chicks on deficient rations died sooner than females. Other factors besides food, such as sunlight and exercise, enter into the problem.

In a comparison of tankage, cottonseed meal, and a mixture of the two, at the Texas station, the cottonseed meal lot gave about 10 per cent more eggs. In a similar test with meat scrap, the cottonseed meal also showed up well.

The addition of sour skim milk, semisolid buttermilk, or meat scrap to a ration consisting of a grain mixture and a mash of ground grains and wheat by-products more than doubled the winter egg production, in experiments at the Kentucky station. Tests at the Iowa station emphasized the value of fresh buttermilk for laying hens.

Twenty per cent of meat meal in rations was replaced by fish meal without causing a fishy taste in the eggs, in experiments at the North Carolina station.

Grains being deficient in calcium, sodium, chlorine, and phosphorus, the addition of mineral matter to the grain or mash ration for ducks was followed by very favorable results in experiments at the North Carolina station.

Culling.—Trap nesting in July and August was found by the Iowa station to be best for accurate culling of the breeding flock.

Passage of food through the fowl.—The North Carolina station found that food passes most rapidly through the intestinal tract of laying and growing fowls, requiring on an average 3 hours 52 minutes for growing fowls, 3 hours 46 minutes for laying hens, 8 hours for adult hens, not laying, and 11 hours 44 minutes for broody hens.

DAIRYING

Breeding.—Close inbreeding for several years, at the Ohio station, starting with good producers, has shown no decrease in fertility, but there has been a decline in milk production and size, with a tendency to a lighter shade in color.

A statistical study by the New York Cornell station of the effect of the age of the parents showed that a large proportion of high producers are the first calves of immature dams, indicating that age of breeding has little effect on the offspring.

At the Ohio station the percentage increase in production from the first to the third generation of Holstein grades, starting with scrub cows with purebred Holstein bulls, was from 61 to 231 per cent in milk production and from 55 to 153 per cent in butterfat production.

Calf feeding.—At the Washington station calves made normal growth on a homemade calf meal, consisting of 40 pounds corn meal, 20 pounds alfalfa leaves, 20 pounds wheat bran, and 20 pounds linseed meal. Two pounds of this mixture scalded in 1 gallon of water was equal to 1 gallon of whole milk.

Gains of calves fed dried and semisolid buttermilk were equal to those fed skim milk, in experiments at the Minnesota station, and the animals remained in especially good health. A ration deficient in vitamin B gave positive results only after a period of eight or nine months. The effect was not very marked even then, and was shown mainly by a poor appetite and general lack of thrift.

Normal growth in weight was made at the Missouri station by heifers when 13.4 per cent of the total net energy for maintenance plus growth was furnished by protein in the ration. Higher protein planes were much more efficient in promoting growth with Holsteins than with Jerseys.

Milk secretion and production.—Studies on a Holstein herd at the Maine station showed that cows with larger measurements had slightly larger yields, but no relation was found between the dam's percentage of butterfat and the daughter's milk yield, or vice versa. There seemed to be a slight relation between the granddaughter's butterfat percentage and that of the maternal granddam, and only a slight relation between the granddaughter's milk yield and that of the maternal granddam. Likewise the relation was slight between the granddaughter's butterfat and the paternal granddam's butterfat. All of the data indicated that only ancestors in the first and second generations have any pronounced influence on the milk yields of their progeny. A cow's milk yield and butterfat percentage can best be predicted from that of her dam and full sisters.

The energy value of the milk solids is, according to the Illinois station, the most equitable basis for the comparison of the production of cows, milk yields being corrected for the influence of fat content, to the physiological equivalent of 4 per cent milk, by the equation F C M=4 M+15 F, where F C M means fat corrected milk, M the actual milk yield, and F the actual fat yield in pounds.

A definite relation between the concentration of the blood and that of the milk during the winter was indicated by investigations at the Missouri station. There was found to be a constant monthly percentage decline in the amount of milk from the second month of lactation, this being regular throughout the whole lactation period. Maximum production was at 7 or 8 years of age. Tests showed that the average monthly decrease in milk production for all breeds was very uniform, the production during the twelfth month being approximately 50 per cent of the production during the best month. The principal variations in milk production, aside from that due to advance of lactation, were found to be caused by changes in pasture during spring and summer. Cows calving in the fall and winter months equaled or excelled the average production, but those calving during the summer were generally below the average. Increase in weight followed closely the increase in milk secretion. Grouping animals of a given weight, regardless of age, showed an increase in production with the weight. Milk production appeared to be dependent upon two factors—age and weight. In Jerseys an increase in body weight of 100 pounds with age was accompanied by an increase in butterfat production of a little over 100 pounds per year. Milk secretion increased with the body weight of the cow to the age when maximum body weight was reached (8 years), when it took a downward course and steadily declined with age. When the ration fed to dairy cows was reduced 50 per cent there was a decided increase in the percentage of fat in the milk, the peak being reached about the third day and remaining so during the test of 10 days. When the animal was put back on normal feed the fat percentage decreased and remained below normal for 10 days. After milking the percentage of fat in the milk secreted fell, reaching a minimum in 16 hours, and then increased somewhat.

The use of milking machines had little or no influence on the yield of milk in experiments reported by the Texas station, but increased the bacterial count unless special precautions were taken.

Soiling versus pasture.—The Montana station found pasture feeding much more economical than soiling, even though slightly less land is required and the production is slightly higher with soiling.

Silage.—Medium-mature corn silage was found by the Pennsylvania station to be better than green silage for milk production, producing about 8.6 per cent more milk. In a comparison of early, medium, and late-maturing varieties of silage corn at the Connecticut Storrs station, all being planted and harvested on the same day, the pounds of silage necessary to produce 1 pound of milk were, for the early 3.5, medium 4.2, and late 5.4. The amount of milk produced per acre was, with the early 7,078 pounds, medium 7,663 pounds, and late 7,525 pounds.

Sorghum silage was found by the South Carolina station to be 95 per cent as efficient as corn silage in the production of butterfat, practically equal to it for maintenance of body weight, and with a slight advantage over corn silage for milk production. It greatly outyielded corn in tonnage per acre.

Sunflower silage proved to be about equal in value to corn silage for the production of milk and butterfat, at the Georgia station. The iodine number and refractive index of the butterfat was slightly higher on the sunflower silage ration. A comparison of

sunflower and oat-and-pea silage for dairy cattle, at the Montana station, gave practically the same results, but as the tonnage of the sunflowers was much greater there was considerable advantage in favor of the latter. A similar comparison of oats and vetch, corn, and sunflower silage, at the Oregon station, showed clearly an advantage for oats and vetch, considering yield, adaptability, cost of production, and feeding value.

Soaked beet pulp proved less palatable than corn silage in experiments at the Utah station, but those animals that would eat it maintained the full milk flow as well as those on the silage.

Soybeans.—A comparison, at the Indiana station, of soybeans, ground or as oil meal, with linseed and cottonseed meals in the dairy ration showed that the ration containing soybean-oil meal plus a mineral mixture required less feed for milk and fat production than the other two supplements, but all were very similar in their effect on production. At the Iowa station dairy cows were fed cracked soybeans up to 4 pounds daily for 100 days, with cracked corn and ground oats, with no unfavorable results and no scouring. Soybean-oil meal was found to have identical value for milk and butterfat production as old process linseed meal. In a comparison of soybean meal and cottonseed meal at the Mississippi station, the former tended to cause a higher fat content in the milk, but there was a greater loss of body weight of cows fed soy beans than those on cottonseed meal.

Milk and cream.—In a comparison of the methylene blue test and bacterial counts as a test for milk, at the New Hampshire station, no very close correlation was found, except in the reduction time of the methylene blue and the keeping quality of the milk. There was no close correlation between the bacterial counts in milk kept until it soured and the reduction time. The initial acidity was no index as to how long a milk would keep. The milk of Holsteins was found to be uniformly lower in initial bacterial count than that of Guernseys or Jerseys, by the South Carolina station. If there was a low initial bacterial count it remained so for some hours, but if the initial count was high it increased rapidly.

Contrary to theories that rennin action involves the destruction of the effects of a protective colloid in milk, it was found by the Minnesota station that a colloidal dispersion of calcium caseinates clotted like natural milk with rennet, at the proper temperature and hydrogen-ion concentration, in the presence of a trace of free calcium ions.

There appear to be eight valences and four distinct compounds of casein with alkali possible, according to studies at the New York State station. One definite compound of casein and calcium has been established with 1.8 per cent calcium. Some of the calcium compounds show plasticity when heated, indicating a colloidal character.

"Albumin" milks, made by mixing whey with cream, gave excellent cream layers, in experiments at the Minnesota station, and pasteurization increased the cream layer, contrary to the results with "casein" milk. Artificial whole milk creamed well at ice-water temperatures, but very poorly after pasteurization at 63° C. for 30 minutes. The removal of soluble salts seemed to have little effect on the creaming of raw milk, but salt-free milk had a very poor creaming ability after pasteurization.

The chemical composition of colostrum was found, by the Missouri station, to change rapidly with each milking, until it became normal milk, on about the third or fourth day. The main change is in the globulin and sugar, the former decreasing rapidly and the latter increasing. Colostrum has a considerably higher hydrogen-ion concentration than normal milk.

Wide variation in the citric acid content of normal milk, which may have a bearing on the selection of milk for the making of starters, was reported by the Iowa station.

Studies on the farm storage of cream, at the Indiana station, indicated that there is a change on the fifth day and that butter made from cream 5 or more days old does not score as high as that 4 days old or less. As a result of this study, creameries are now paying a premium for cream not over 4 days old and this practice has been adopted by seven or eight neighboring States.

Butter.—Butterfat heated to 175° F. for three hours and stored at temperatures of 0 to 35° kept well as compared with butter and cream so treated, in experiments at the Vermont station. Butter oil was held at a higher temperature than ordinary cold storage for several months, the change in temperature not having so much effect on it as it did on butter.

With butter that would not stand storage, the oil was separated, stored, and made over into a good product, first being made into a cream and from this into butter, which was scored high by experts.

Salt had no noticeable effect on the keeping qualities of sweet-cream butter or in preventing hydrolysis of the proteins, in tests at the Indiana station.

Contrary to the general belief among butter experts, the presence of large quantities of peroxidase in butter had no detrimental effect on the quality after six months' storage, in experiments at the Minnesota station.

Butter made from poor cream with a high bacterial count, which had been pasteurized, was found by the Michigan station to contain the enzyms capable of ruining the butter.

Fishy flavor of butter was found by the Wisconsin station to result from bacterial decomposition of lecithin, with the formation of trimethylamine, due to high acid, high salt, or oxidation as a result of overworking in the presence of iron or copper salts.

A distinct metallic flavor resulted from hanging strips of copper, iron, and zinc in milk cultured for buttermilk beverage, in experiments at the Oklahoma station. Tin and aluminum did not produce this effect.

Cheese.—Clarification of milk was found by the New York Cornell station to change only slightly, if at all, the composition of milk. The fat loss in the whey was slightly less with clarified milk than with the same milk not clarified. Clarification affected the yield of cheese as a result of losses during the process of manufacture and the moisture incorporated with the cheese. Clarification improved the quality of the cheese, and such cheese kept better in storage than that from unclarified milk.

The "stinker" odor in Swiss cheese was found by the Wisconsin station to be due to a combination of organisms, which may readily occur in milk, rather than to any single type of organism.

Ice cream.—Studies at the Illinois station showed that proper homogenization of an ice-cream mix improved the texture and resistance of the resultant ice cream. Homogenized mixes required less milk solids than unhomogenized to produce ice cream of equal quality. The temperature and pressure employed in the homogenization process affected the texture and resistance of the ice cream. It was possible to secure greater overrun from homogenized ice-cream mixes than from unhomogenized.

A direct relation between the percentage of sugar added to the mixture and the hardness of the finished ice cream and its ability to stand exposure to summer temperature, was shown by the Missouri station. With increased increments of butterfat, the viscosity showed a gradual increase. The time required for the mixture to begin freezing varied directly with the fat content, and the time required to whip the mixture decreased with increased fat content, resulting in a decrease of the total time required to freeze. The overrun increased slightly with increased viscosity. Ice cream containing the higher percentages of butterfat retained its original form over a longer period of time. Ice creams with 10 to 12 per cent of butterfat gave the best flavor, body, texture, and salable condition.

A bacteriological study of ice cream, by the Kansas station, in cooperation with commercial creameries, showed efficiency of pasteurization to be the most important single factor governing the bacterial content of ice cream, that it is practicable to produce ice cream containing fewer than 100,000 bacteria per gram, and that when it contains excessive numbers there is some factor in the process of manufacture that has been neglected, which may be a low grade of material, inefficient pasteurization, unclean utensils, or failure to control the temperature of the mix during the aging process. The use of homogenizers was found to increase bacterial count, by breaking up the clumps of bacteria.

Studies of gelatin for ice cream, at the Oklahoma station, showed that the quality of the gelatin varies greatly, and much contains large numbers of bacteria. An apparatus has been devised for testing strength, consisting of a plunger dropping into a 5 per cent solution of the gelatin, held over night to jell. This is now on sale and it is believed it will lead to a standardization of this material. Studies on factors affecting viscosity showed that acidity is not necessary and that an overrun of 100 per cent can be produced without it.

The rate of development of viscosity is not in direct ratio with acid development and is most rapid during the first 48 hours, according to the Georgia station. Pasteurization decreased the viscosity of the ice-cream mix, but on aging for 48 hours the pasteurized mix regained its viscosity to some extent.

Tests of acidifying the mix, at the Nebraska station, showed that the frozen cream retains the lactic acid flavor and is objectionable. It serves no useful purpose as it has no noticeable effect upon the physical make-up during the aging and freezing of the mix and is not recommended. Excessive aging tended to decrease the viscosity of the mix and caused a decrease in its ability to preserve a smooth texture. The optimum aging period for a normal mix was between 24 and 48 hours.

The percentage of total solids was found by the New York Cornell station to be the determining factor in sandiness.

The size of the air cells and water crystals was shown by the New York State station to be the main factor in the smoothness of ice cream. A greenish black discoloration which sometimes occurs in chocolate ice cream was found to be caused by rusted iron on the ice-cream can combining with tannin in the cocoa to form an iron tannate. Cocoas were found to vary largely in tannin content. The discoloration can be prevented by the use of well-tinned or paper-lined ice-cream cans.

VETERINARY MEDICINE

Horse diseases.—Swamp fever was not transmitted to the horse after passing it through the pig, at the Texas station. Pigs showed no change in temperature when inoculated with strong virus. The Wyoming station found the virus of this disease in the nasal secretion of infected horses.

The North Dakota station reported the death during the year of a horse which had been a carrier of swamp fever in mild form without anemia since 1908, but finally developed an acute and quickly fatal form of the disease. Salvarsan was tested as a treatment, with negative results.

In studies of orchard horse disease at the Washington station, it was not possible to produce a typical chronic case by the administration of lead arsenate. It appears that while this compound is probably primarily responsible for this disease, it does not produce it as a poison in the animal's body. The arsenate appears to produce in the growing alfalfa plants some change, as yet unknown, which causes the disease.

An apparently new species of streptococcus has been found in a number of cases of uterine infection in mares, by the Kentucky station. Vaccine prepared from it is apparently valueless and antistreptococcus serum also seemed to have no value.

Cattle diseases.—Blood taken from Brahman cattle, supposed to be immune to the tick and to Texas fever, and inoculated into Herefords raised above the quarantine line, transmitted the disease in one case at the Texas station. The Brahmans gave little temperature, being very resistant to the fever, although not absolutely immune.

Studies by the Texas station of an unidentified disease know as "down in the back" gave no indication of its cause and no positive evidence that it is due to poisonous plants. Culture of one organism from the disease produced it for a while and then became ineffective. The disease was produced in cattle by feeding ground bones from cattle that had died of the disease, the lesions being the same as in the field cases.

Studies of an unidentified hemorrhagic disease of cattle at the Nevada station indicated that it was due to joint or successive action of a number of microorganisms working together under favorable local conditions of food, water, and soil. There are indications that a protective serum or vaccine may be successful. Studies of an obscure disease of range cattle at the Wyoming station indicated the possibility of its being botulism.

In studies of sterility in cattle at the Minnesota station, cystic degeneration was found to be the most common pathological condition affecting the ovary. Prolapse of one or both walls of the vagina was found to be a fairly common condition in both dairy and beef cattle and a factor in sterility.

Sheep diseases.—It has not been possible to connect ictero-hematuria in sheep in any way with ticks at the Colorado station or to produce the disease by placing ticks on sheep.

In studies of pneumonia in sheep at the Montana station, cultures from infected animals gave either one of the Pasteurella group or a diphtheroid bacillus as the causative organism. In inoculation experiments the diphtheroid organism was recovered from the lungs of sheep inoculated with that organism, but no results were obtained with Pasteurella and it is believed that the diphtheroid bacillus is the causative organism. The disease develops very slowly under good care. Culling and immediate marketing of sheep showing symptoms are recommended for control.

Feeding experiments with sachahuista (*Nolina lindeheimerina, N. tex-*

ana, and *N. erumpens*), which are thought to be a cause of swell head in sheep and goats, gave negative results at the Texas station.

Swine diseases.—In studies of the posterior paralysis of swine at the New York Cornell station, lack of minerals was found to be definitely connected with the development of the trouble in some cases but not in others. Histological studies suggested scurvy as well as improper mineral assimilation. It is believed that at times the symptoms may be connected with rickets and at other times with scurvy, or that both may occur simultaneously.

Swine dysentery was found by the Indiana station to be a definite disease with diphtheritic mucous membrane lesions in the colon. Amœba, spirilla, balantidia, and comma-shaped organisms were found in the colon, but these were not successfully grown in cultures. Pig typhoid was found to occur most frequently in late winter and early spring pigs. It was not possible to reproduce the disease by placing healthy pigs in lots with sick animals with two or three months' exposure. The history and lesions suggest food deficiency as one of the causes.

Poultry diseases.—Aspergillosis in chickens was found by the Oklahoma station to be caused by a black mold, causing heavy losses in some cases. The mold spores become more virulent by passing through poultry. Renal coccidiosis of poultry was found to be similar to blackhead in turkeys, but is confined to the kidneys and intestines, and is scattered in the droppings, this being the only source of transmission. It is best treated by sulfur carbolate in the drinking water.

In white diarrhea studies at the Rhode Island station, two different strains of *Bacterium pullorum* have been found which agglutinate differently but show no other differences and grade into each other. Reaction was sometimes obtained with one strain in apparently healthy birds, but not with the other. Temperature had no effect on the occurrence of the disease. Tests at the Kansas station showed that 100 per cent mortality may result from inoculating fertile eggs with *B. pullorum*. The disease had a marked effect on the hatchability of eggs, which was lowered; but not all eggs laid by an infected hen contained the organism, and the hatchability was dependent upon the number of organisms present in the egg, the virulence of the organism, and the resistance of the chick embryo.

A paratyphoid organism was isolated from cases of "keel" of ducklings, by the Connecticut Storrs station, which resembles *Bacterium anatum*, and its relation to the disease was demonstrated. Autopsies showed pathological changes in the ovaries. Four strains of the organism were isolated from different localities. The organism does not react to *B. pullorum* serum. The disease is very fatal.

Studies of leg weakness in chicks at the Indiana station showed that the trouble developed commonly when the chicks were kept indoors until 4 to 6 weeks of age and could be cured by feeding them cod liver oil or by putting them outdoors in the sunlight. The bones showed the same changes as occur in rickets in other animals.

Examination of a large number of cases of roup in chickens at the Michigan station indicated that a great deal of so-called roup is not primarily infection but is due to nutritional disturbances, sometimes associated with faulty diet and sometimes with intestinal parasites.

The North Carolina station found fowl septicemia to be due to the same cause as fowl typhoid, the organism being identified as *Bacillus sanguinarium*. Typical disease was produced with cultures of this bacillus, and a vaccine was prepared that was effective in stopping the disease.

Anthrax.—Studies at the Louisiana station show *Tabanus fulvulus* to be one of the most common and certain carriers of the anthrax organism. This fly feeds freely on all kinds of quadrupeds and acts wholly as a mechanical carrier. Five other species of Tabanus and two of Chrysops were found to act as carriers, while three other species of Tabanus did not carry the disease. Experimentally *T. fulvulus* gave 50 per cent of experimental infections with guinea pigs, other carriers producing less. The virulence of the organism was not reduced in the soil, soil water, or stagnant or running water, nor was its vitality destroyed by alternate moistening and drying. Vaccines were found to be efficient preventives.

Hog cholera.—The Indiana station found that cholera blood of known virulence spread on glass plates in a thin layer and exposed in a well-lighted room for 7 days in August, when fed and injected subcutaneously into pigs, produced symptoms of the disease; but, with virus so exposed for 8 to 9 days, none of the pigs developed symptoms. Urine from a cholera hog 7 days after inoculation with virus did not produce the dis-

ease when fed to susceptible hogs, but the feces were virulent. The urine of a hog 10 days after inoculation was infectious. In the early days of inoculation, the urine was apparently nonvirulent. Virus died out in a short time in a decomposing body.

Hemorrhagic septicemia.—In experiments at the Nebraska station virus prepared from strains of *Bacillus bipolaris septicus* as bouillon cultures incubated for 24 hours showed marked protective qualities but induced only an evanescent passive immunity which disappeared within a week. Injection of virulent cultures into animals treated with serum did not make the immunity more lasting. The Colorado station has isolated a large number of strains of the bacillus.

Tuberculosis.—It was found at the Wyoming station that injection of the avian type of tuberculosis into cattle produced lesions very similar to the skin form of tuberculosis in cattle. The injected animals gave positive reactions to the intradermal tests for tuberculosis but negative or doubtful reactions to the subcutaneous and ophthalmic tests.

The examination of material from 26 tuberculous swine at the Nebraska station showed at least 21 to be definitely of the avian type, and on all the farms from which these hogs came the poultry flocks were found to be infected, but on only one were the cattle infected.

The avian type of tuberculosis was also found by the Wisconsin station to be more common in hogs than the bovine type, and avian and porcine tuberculosis were shown to be intertransmissible. A bacteriological study of one lot of tuberculous hogs, however, showed only 2 cases to be avian, 13 being bovine.

Experiments at the Illinois station also suggest that the avian type of tuberculosis may be communicable in some degree to other animals. Calves and pigs may be infected experimentally, but the lesions so induced are generally benign in character. Pigs fed chicken with tuberculosis of the avian type showed lesions in the mesenteric lymph glands. The tuberculous lesions induced in pigs by certain strains of the avian organism, upon feeding and injection into healthy chickens failed to produce typical lesions of tuberculosis, suggesting that the initial avian infection in swine may not be highly communicable, but some strains are readily transmissible from chickens to swine and back to poultry with the production of characteristic lesions. English sparrows and pigeons may contract the disease from chickens. The tuberculous infection of the English sparrow may be communicated to poultry and pigs by injection or feeding the tuberculous tissue or the cultures of the organism.

Parasites.—*Sarcocystis tenella* was found to be a common parasite in the muscle of sheep by the Wyoming station. Infection was light in the dry lot but heavy in pastures. The disease was transmissible directly through fecal infection and was therefore higher where animals are confined to a limited area. Experiments with animals kept in screened inclosures to prevent insect transmission gave negative results. Infection occurred from late spring to late fall. There appeared to be no infection with the tapeworm (*Thysanosoma actinioides*) in dry lot, and infection was not very often harmful.

A study of the stomach worms of sheep at the Texas station showed that copper sulfate and sodium arsenate mixtures were not wholly effective. A 100 per cent kill was not secured with copper sulfate in maximum doses with sheep, but was more successful with goats. With goats a 3 per cent solution can be safely used, but with sheep it is not safe to use stronger than a 1.5 per cent solution. Carbon tetrachloride and nicotine sulfate gave good results as agents to eliminate the worms. Like results were obtained with nicotine sulfate at the Connecticut Storrs station. Copper sulfate was not so effective.

Bromoform was found to be very effective in killing the screw worm, in experiments at the Texas station, when used in small quantity under a covering of wool or cotton, and it is not so irritating as chloroform. The most effective fly repellent tried was pine tar 50 per cent, glycerine 25 per cent, and castor oil 25 per cent. The goat louse was shown not to occur on wild animals, and would not stay upon them when so placed. For its control a standard arsenical dip, with two dippings at 10-day intervals, was most effective.

The Oklahoma station found lye to be useful in ridding infected poultry of tapeworms. Roundworms responded better to tobacco than to lye, and carbon tetrachloride was also effective. At the California station a single treatment of nicotine sulfate with aluminum silicate given in capsules was found to be 100 per cent effective

for *Ascaridia galli*, and combined with tobacco dust 85 per cent effective for cæcal worms.

It was found at the Kansas station that 24 per cent of young birds die in from 10 to 14 days after infection with nematodes, the survivors being resistant and doing well thereafter. The Rhode Island station found that Heterakis does not migrate in the body of the bird. It causes irritation in the cæcum which may, perhaps, lead to blackhead. At the North Dakota station, sodium fluoride used either by dipping or dusting was effective in destroying lice, but resulted in some decrease in egg production. Mites were controlled by a 5 per cent solution of creolin in kerosene oil.

Poisoning.—In studies on white snakeroot poisoning, at the Indiana station, horses fed 1 pound a day of the weeds cut in the fall, dried, and kept for three months first developed symptoms in five days, which increased until death occurred on or soon after the eleventh day. The symptoms differed from those getting the plant in the field, where the effects show quickly as nervous symptoms. Cattle die from it quickly, often without showing symptoms. Pigs showed no ill effects from eating the weed. Chemical studies show that the toxic principle is very volatile and is probably a glucoside.

Poisonous plant studies at the Nevada station showed that Tetradymia has a high percentage of volatile oil but this does not carry the poisonous principle which is found in the benzol extract. It was most abundant in the young growing tips. *Atriplex canescens* is believed to be poisonous to sheep at any stage of growth. It contains a saponin, believed to be the poisonous principle, which produces homolysis. A small buttercup with toxic properties has been found. Feeding experiments with larkspurs have failed to show any poisonous effects. Studies of the alkaloidal poison of *Delphinium menziesii*, at the Wyoming station, show that this species is the most poisonous of all the larkspurs. Two types of toxic alkaloid were found to exist in *Lupinus argenteus*, one solid and the other liquid.

TECHNOLOGY

In investigations at the Louisiana station on the clarification of cane juice and the deterioration of cane sugar it was found that a reversal of the usual procedure of sulfitation, in which the juice is first clarified with lime and then lightly sulfured to attain a bleaching of the coloring matters, gave excellent results if carefully carried out. It gave a much better elimination of impurities, particularly of lime salts, and much less sulfur was required, reducing the sulfur content of the molasses. It was found that filtration with carbons changed the predominant type of organisms in juices and retarded the rate of development of those remaining.

It appeared that to conform to the "factor of safety" a sugar must be crystallized from a solution of such purity that it will yield an exhausted molasses as a protective film for the crystals. Sugar deterioration was shown to be dependent upon surface exposure as well as upon density of the film of molasses surrounding the sugar crystals.

A great variation was found in the inverting power of the mold fungi causing the deterioration of sugar. They were very susceptible to carbon dioxide and by introducing certain races of Torula, or nonsporulating yeasts, these grow on the molasses film of the sugar, producing carbon dioxide, and prevent the molds from developing. This has additional advantages in that their destruction of the reducing sugars and their action on invertase cause an increase in the polarization of the sugar during storage, and by the elimination of levulose and other reducing sugars make it less hygroscopic and hence less susceptible to moisture absorption and resulting deterioration. It was found that the condition of infection of sugars, quantitatively and qualitatively considered, had a marked influence on the keeping quality. The method was ineffective when applied to sugars which contained their original molasses film. The most important factor contributing to the hygroscopic nature of white sugars was found to be the presence of fine grains and sugar dust.

At the Minnesota station, conclusions from two seasons' investigations of the possibility of making sirup from cornstalks are that a good quality of cooking sirup can be made from sweet cornstalks but that a table sirup can not be expected. Since the smaller varieties yield only 30 to 40 gallons per acre and the larger ones 100 gallons or more, the manufacture of sirup will be feasible only when the larger varieties are used. Under proper conditions the manufacture of sirup as a cannery by-product may be a profitable enterprise.

In studies on vinegar making, at the Iowa station, alcoholic fermentation was found to be complete in about a month, acetic fermentation begin-

ning before the alcoholic ended. Good vinegar was made from frozen apples if they were promptly used, no starter being required.

AGRICULTURAL ECONOMICS

Farm management.—A study of exceptionally profitable farms in a series under observation at the Kentucky station indicated that the principal factors responsible for their success were (1) that the labor and teams were so handled us to secure maximum efficiency, (2) that crops were limited to an acreage that could be cultivated well at a moderate cash outlay, (3) that the tobacco produced was of high quality, and (4) that a large proportion of the farms was in grass and more livestock was kept than on the average farm in the section.

Cost of production of wheat.—Studies on the cost of production of wheat, at the Kansas station, in 1922, showed this to be $1.30 to $1.40 per bushel where there was an average yield of 14 bushels per acre, the product selling at $0.90 to $1.05. In a study of the marketing of Kansas wheat, the owners of 63 per cent of the wheat involved in the study believed in and practiced farm storage, 13 per cent did not believe that it pays to store wheat but were compelled to store because of marketing difficulties, 5 per cent believed it paid to store and had facilities but nevertheless sold direct from the machine, probably because of credit factors, 3.5 per cent believed in storage but lacked space, and 8 per cent sold directly from the machine, believing that practice paid best in the long run. Less than 5 per cent of the wheat crop was found to be marketed early because of insufficient farm storage space.

Cost of producing apples.—Results of a study of 64 orchards by the Minnesota station, totalling 487 acres, showed the average cost to be $0.839 per bushel and $125.60 per acre. The average returns were $1.53 per bushel and $215.99 per acre.

Cost of milk production.—Data secured by the Wisconsin station show that on farms whose herds sold less than 5,000 pounds of milk per cow per year there was a return of 3.3 per cent interest on the total farm investment, with no compensation for time; those with 5,000 to 7,000 pounds of milk per cow received 4.7 per cent interest with no compensation; and those with over 7,000 pounds per cow received 5 per cent and $244 for their time.

In data from 172 farms, secured by the Washington station, the cost of producing milk varied from $1.81 to $4.56 per 100 pounds. The basic requirements for producing 100 pounds were grain, 17.7 pounds; hay, 38.2 pounds; succulents, 47.1 pounds; pasture, 3.1 days; and man labor, 2.3 hours.

AGRICULTURAL ENGINEERING

Noteworthy progress has been made in developing investigation in agricultural engineering at the experiment stations. Some more recent examples of work in this field are as follows:

Tractors.—The Nebraska station found that in general total engine weight of tractors increases as the engine weight per brake horsepower increases. The general trend is also toward a reduction in the tractive efficiency with an increase in the total weight of the tractor beyond 4,500 pounds and a decreased efficiency with tractors lighter than 4,000 pounds. With the wheel tractor the tractive efficiency tends to decrease as the total weight per drawbar horsepower increases, varying inversely as the weight on the drivers per drawbar horsepower. It was also found that the lightest weight tractors are not so efficient as those of medium weight, except in the case of live-axle-driven machines. A slight advantage is also noted in the gear drive over the live-axle drive, and no one number of gear reductions apparently has the advantage with respect to tractive efficiency.

Fuel consumption tended to increase with an increase in the piston displacement. The lowest fuel consumption was secured with engines having a cylinder diameter of between 5 and 6 inches. With horizontal cylinder engines the fuel consumption tended to decrease as the weight increased up to approximately 7,000 pounds, after which the reverse was true. In the case of vertical cylinder engines there was a slight increase in fuel consumption until the 7,000-pound mark was reached, after which there was a marked decrease. The I-type engine gave better fuel economy than the L-head engine on all operating loads. The rated brake load gave better fuel economy than either the maximum or half loads. The fuel requirement on drawbar work was almost double that required on belt work per horsepower hour.

In tests of a number of representative fuel treating materials at the Nebraska station, about the same results were secured by proper adjustment of the carburetor without fuel savers as when these were used. Experiments at the California station in-

dicated the importance of proper carburetor adjustment on fuel economy and the impossibility of readily detecting rich mixtures by engine performance.

Experiments on wheel slippage at the Nebraska station indicated a tendency of the angle lug to pulverize the surface of the test track, after traveling over it several times, to such an extent that a good grip could not be secured. The spade lugs gave the best results on the track, due largely to the fact that they penetrated the ground to a sufficient depth to give a good grip and did not pulverize the surface. There was a slight decrease in the percentage of slip of the drive wheels as the total tractor weight increased.

Soil tilth.—Studies at the New Jersey stations showed that while limed soils have a distinctly superior crumb structure, as interpreted on the basis of modulus of rupture, factors other than the direct flocculation of the colloidal material of the soil through the action of the lime are active in promoting this condition. The action of lime was distinctly differential, depending apparently upon the nature and type of the soil. In a clay soil the effect of liming was more or less promptly noticeable through a decrease in the modulus of rupture. In a loam soil the tendency was apparently in the opposite direction. The modulus of rupture decreased with the progressive neutralization of the alkalinity of both natural and synthetic alkali soils.

Duty of water in irrigation.—Experiments at the New Mexico station indicated that the average duty of water on alfalfa was 4.67 acre-feet per acre producing 5.47 tons per acre. The largest yield per acre-foot of water was produced on the soils receiving the smallest head, regardless of the length of plat. Studies at the Utah station have resulted in the development of a mathematical method of determining the economical use of irrigation water under various conditions of water supply, irrigable land, cost of crop production, and value of crops.

Soil moisture movement.—Studies at the Arizona station on mesquite and cottonwood soils showed that in the summer the water table falls as much as 5 inches during the day and recharges during the night. There is no such fluctuation in winter, except that which may be accounted for by barometric pressure.

The maximum movement either upward or downward of moisture from a moist soil into a dry soil was found by the California station to be less than 7 inches during a period of 4.5 months. The presence of a water table did not decrease the rate of percolation, and an increase in head resulted in a greater loss by percolation. The rate of percolation through a gravelly phase of a sandy loam was about twelve times greater than through loam, all other things being equal. The variations in the rate of percolation were dependent upon the effective head operating on the soil column, which varies according to the dispersion of the soil colloids, the loss or gain of organic material, the gradual silting up of the pore spaces of the soil, and the loss of colloidal or fine clay material in the drainage water. The effective head also varied with the flow of water at any point in the soil column and was dependent upon time. The hydraulic gradient in a column of soil with a head of water operating upon its surface is represented by a uniform curve which approached a straight line in about 10 days. A dilute solution of copper sulfate increased the rate of percolation by altering the soil structure.

Tests at the Washington station showed that on land having a slope of 0.2 foot per 100 feet water penetrated to a depth of 4 feet in 48 hours, while on land with a slope of 6 feet per 100 feet it penetrated only 3 feet in 72 hours. The rate of lateral distribution was about proportional to the downward penetration in each case. The lateral and downward movements of water from a furrow were nearly equal for the first 12 to 24 hours, after which the lateral movement slowed down to almost nothing in from 36 to 48 hours.

The yield and net profit per acre-inch of irrigation water were almost doubled by rotation and manure and the water requirement per pound of dry matter was reduced nearly one-half in experiments at the Oregon station. A rich and well-balanced nutrient solution in soils resulted in a low water requirement for crops.

Soil moisture conservation.—Results of studies at the California station indicate that the hygroscopic coefficient is the most logical point upon which to base all calculations relating to the moisture content of the soil.

Evaporation within and without the laboratory showed very similar characteristics in studies at the Colorado station, but the maximum rate did not occur at the same time of day. The effect of wind on the rate of evaporation was very marked. Studies at the Utah Station showed that

an effective mulch of 1 inch of straw is capable of holding 60 per cent more moisture in the soil than is retained without mulching. The loss of moisture from the soil was correlated with the percentage of moisture retained by the mulch. The effectiveness of mulching and cultivation increased with their depths, and the rate of evaporation from soils under mulch varied according to their moisture contents, the finer soils losing the most water. While cultivation and soil mulching saved moisture, the evapotranspiration ratio was least with no mulch or cultivation. Fall plowing conserved more moisture than spring plowing and 4-inch cultivation was more efficient than 6-inch cultivation.

Irrigation of alkali soils.—The California station found that alkali water may be passed through certain soils for some time without causing an accumulation of salts in the soil. Sodium carbonate may produce bad effects on the soil very quickly, but this may be largely or entirely prevented if chemically equivalent amounts of gypsum are added to the water before applying it to the soil. The presence of calcium carbonate and organic matter such as alfalfa meal may still further counteract the injurious effects of alkali water on soil.

A condition of impermeability was found by the New Mexico station to develop on leaching an adobe soil containing about 1 per cent of sodium chloride. With good percolation this large amount of alkali was readily removed and leached below the toxic limit by a small amount of water. The chlorides were more readily removed than any other constituent.

In attempts to reclaim alkali soils by leaching with water and adding gypsum, the California station found that the removal of all but negligible amounts of alkali salts from the first 6 feet or more of a heavily impregnated soil required many months of leaching. Soluble matter not carried below the 6-foot level was found to return near the surface with the capillary water. Gypsum, acting as a flocculant, increased the rate of leaching. Chloride, nitrate, sulfate, carbonate, and bicarbonate were leached out in the order given. The removal of more than 0.5 per cent of sodium carbonate from a soil was a very slow process. Similar results, with special reference to the ease of removing sodium chloride and the difficulty of removing sodium carbonate, were obtained at the Utah station. The long unproductive period frequently following the leaching of alkali soils appears to be due to the removal of much of the readily available plant nutrient material, the poor state of tilth of the drained soil, and the occasional production of toxic lime-magnesia ratios.

Irrigation structures.—Experiments at the Arizona station showed that concrete linings of from 1 to 2 inches in thickness have been used successfully in irrigation canals in regions where the frost action is not serious. Present practice tends to make 1.5 inches the minimum thickness, but a greater thickness should be used for large canals and steep side slopes. Canals located on unstable foundations require increased thickness, beam effects, and reinforcing to resist side and bottom pressures and unequal settlement.

Sewage disposal systems.—Investigations at the Michigan station extending over a period of eight years indicate that the proper farm sewage disposal system for Michigan conditions involves the use of four units and two distinct processes of bacterial action. The units are an anaerobic and settling chamber for the decomposition of solids, a siphon chamber, a siphon, and an aerating system.

Biology of sewage disposal.—Studies at the New Jersey stations showed that very few fungi and algae occur in the Imhoff tank. The protozoa apparently increase in number with increasing depth, and as a rule the scum formed in the vents of the tank does not contain protozoa at all. The more abundant bacteria in Imhoff tanks are those which attack the most easily digested protein material. These bacteria were always present even in the highest dilutions, and their numbers apparently bore some relation to the character of the protein molecule. Both nitrification and nitrate reduction occur in the Imhoff tank. In nearly every case the scum in an Imhoff tank was found to be decidedly less alkaline than the influent and in nearly all cases less alkaline than the preliminary sludge, ranging in reaction from pH 6.8 to 7.6. A total absence of oxygen and hydrogen occurred in Imhoff tanks. Studies on sprinkling filters showed that the slimy film is composed largely of bacteria, microscopic animals, and fungi. The greater part of the effective nitrification was found to take place at the bottom of the filter bed throughout the whole year. Denitrification exceeded nitrification in the upper parts of the bed in the spring, and free ammonia was removed chiefly at the bottom of the bed.

Dairy sewage disposal.—Studies at the New York Cornell station showed that natural processes tend to destroy dairy wastes and render them harmless in a manner similar to that in which they assist in the purification of other organic wastes, and that supplemental methods of purification are needed only when the amounts of waste present are in excess of those which nature can handle without the development of undesirable conditions. It was found that from 75 to 95 per cent of the organic nitrogen could be removed from whey by adding a slight excess of lime over that necessary to neutralize acidity, boiling, and then passing the cooled effluent through a septic tank and a sand filter. The activated sludge method of treating dairy wastes proved impracticable. A sand filter purified milky waste septic tank effluents at rates ranging from 75,000 to 100,000 gallons per acre per day. A stone or lath filter purified such effluents at rates ranging from 300,000 to 400,000 gallons per acre per day. Some form of settling and holding treatment for milk wastes was found to be desirable. An Imhoff tank was found undesirable for this purpose. A septic tank, which should be designed to hold from one to three days' flow of waste, is recommended. Secondary sedimentation tanks were found to be a necessary part of a treatment plant in which the filter material is coarse. Milk wastes could be sufficiently purified by tank and filter treatment so that fish showed no distress in the undiluted effluent.

Drain tile.—Studies at the Wisconsin station showed that the better grades of concrete drain tile compare favorably with good shale tile, but only the best show signs of permanence in peat. In general, comparatively poor concrete tile will stand up well in clay subsoils. Clay or shale tile that absorb water to the extent of more than 14 per cent of their dry weight are undesirable, and concrete tile with an absorption greater than 7 per cent are too porous for use in peat or sand under peat. The deterioration of concrete in peat is less marked where dense walls are secured by firm packing, which seems practicable only in the thick walls of tile 12 inches and larger in size.

STATION WORK ON INFECTIOUS ABORTION

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BOVINE INFECTIOUS ABORTION

Importance.—Infectious abortion is probably the most important insidious disease with which the livestock farmer of this country has to contend and presents, according to the Michigan station (*1*),[1] the greatest economic disease problem which confronts the breeder of purebred cattle. According to the Connecticut Storrs station (*2, 3*), it ranks with tuberculosis and hog cholera in importance and is more insidious even than tuberculosis and more far-reaching in its after effects. It not only causes loss of the calf but results in decreased milk flow, possibly permanent sterility of the cow, and in other harmful effects.

The Arkansas station found (*4*) that in some sections 70 per cent of all cattle herds are infected. Tests by the Wyoming station (*5*) showed a large percentage of cows on the range to be infected. The Wyoming station (*6*) concludes from observations made in that State that a large percentage of the so-called dry cows are sterile because of abortion infection.

Cause.—*Bacillus abortus* is generally considered to be the cause of the abortion disease, but the California station (*7*) has found herds in which abortion occurred, although agglutination tests for *B. abortus* were negative. The station found *B. abortus* to be present in the supramammary lymph nodes of first-calf cows, the blood of which was negative to the agglutination test. In a small percentage of cases, negative for *B. abortus*, organisms including *Vibrio fetus* and possibly *Bacillus pyogenes* have been found, that must be taken into consideration (*8*). The results of investigations at the Kansas station seem to suggest that *B. abortus* is not the sole incitant of abortion disease (*9*). Agglutination tests of the blood of range animals in the mountainous district of Colorado (*10*) indicate that a considerable proportion of the abortions in such herds in the State may be due to some factor other than *B. abortus*. The Oregon station (*11*) found many animals that had aborted but failed to give positive blood tests. However, *B. abortus* is stated to be responsible for 90 per cent of all abortions in Oregon (*12*). Studies at the Michigan station (*13*) indicate that there is a large number of nonvirulent strains of *B. abortus*.

The Missouri station (*14*) found that *B. abortus* infection may localize in the liver and probably also in the spleen, as occurs in guinea pigs.

Cultivation.—Maximum growth of *B. abortus* was obtained at the Oklahoma station (*15*) by using media that had an H-ion concentration of 7.4. A rapid method for the cultivation of *B. abortus* perfected by the Minnesota station (*16*) consists in the use of horse serum agar culture media, using 10 per cent naturally sterile horse serum and adjusted to approximately pH 7–7.2. Cultures made on such media and incubated in an atmosphere of 10 per cent carbon dioxide or hydrogen showed colonies at the end of the 24 hours and reached a maximum growth in 72 hours.

Substitution of liver or spleen for the beef of the ordinary beef agar was found by the Michigan station (*17*) to give a medium in which growth of *B. abortus* was much more rapid than on ordinary beef agar. The spleen medium was further improved by the addition or 1 per cent starch or 1 per cent dextrose, or both, while the liver agar did not require the addition of carbohydrate. The use of an anaerobic jar as a container of the culture tubes was found to be more efficient and convenient than sealing the individual tubes with sealing wax. The medium found most satisfactory by this station (*18*) for the isolation of *B. abortus* from milk was liver infusion agar in which was incorporated sufficient gentian violet to give the dye a final dilution of 1 : 10,000. The medium was adjusted to an H-ion concentration of between pH 6.6 and 6.4 by the colorimetric method, using brom-thymol blue as indicator. The medium should be prepared without

[1] Numbers in parentheses refer to references, page 81.

excessive heating and filtered through glass wool instead of cotton or paper.

Diagnosis.—The complement fixation method was not found to be superior to the agglutination test for diagnosis of abortion, in tests reported by the Minnesota station (*16*). Remarkably close agreement in results was obtained by the two methods in a comparative study at the Kentucky station (*19*). The conclusion was reached, however, that it is very rare for cows to show agglutination in dilutions of 1 to 100 or above, unless they have been infected recently, and that it does not seem practicable to use the agglutination method alone. Both have been used with success at the Connecticut Storrs station (*2*) and the Wyoming station (*5*). The agglutination test was found by the Indiana station (*20*) to be valuable in diagnosing herd abortion, but not adequate for the more accurate diagnosis of individual cases of abortion.

A detailed account of the complement fixation test has been given by the Wisconsin station (*21*), but since this test is very complicated the agglutination test is more commonly used (*22*). Although, as pointed out by the Connecticut Storrs station (*2*), these reactions do not of necessity indicate that an animal is at the time of examination infected with *B abortus*—the disappearance of the organism from the host not being followed immediately by a similar disappearance of the antibodies—yet there is no doubt that such an animal, if not at the time infected, has within the past five or six months been an active carrier of *B. abortus*.

There is no definite correlation between a positive agglutination test and abortion, according to the Illinois station (*23*); but the presence or absence of infectious abortion in the herd may be established with accuracy by the serum agglutination test of all breeding animals.

From studies with guinea pigs the Michigan station concludes (*24*) that the intradermal test may be used to detect infection with *B. abortus* in connection with complement fixation and agglutination tests to differentiate between infection and immunity. Similar intradermal tests on cattle indicate that the test may be employed as a means of detecting animals which harbor live abortion organisms in their bodies.

The agglutination test, according to the Wisconsin station (*25*) must be made at least once every six months in order to detect incipient cases of infection. The application of the agglutination test to 2,400 animals in the herds in one community indicates, according to this station (*26*), that the test is an effective and practical measure for use in abortion control. This station's experience is considered to point the way to the possibility of establishing abortion-free accredited herds. Single negative agglutination tests, according to the California station (*7*), are not to be taken as definite evidence of the disappearance of *B. abortus* from the body of infected animals. The Oregon station (*27*) found a single maximum agglutination to be of no value in determining whether a cow will abort.

Repeated intravenous injections in experiments at the Minnesota station (*28*), and also injection into the sheath of pure culture of *B. abortus* raised the agglutination titer of the blood of young bulls; but the antibodies gradually decreased and *B. abortus* was not isolated in any case, even though the organs were carefully examined after slaughter. It was found that the blood of young calves did not have the same agglutination titer as that of their dams (*16*). Calves were found to give the same agglutination reaction as their mothers in experiments at the Connecticut Storrs station (*2*, *29*) and the Wisconsin station (*22*). The Connecticut Storrs station (*2*) found that after six months all calves were nonreactors. Thec omplement fixation test showed no advantage over the agglutination test in comparative trials at the Minnesota station (*16*). This station (*16*) found that the ingestion of colostrum quickly affects the antibodies present in the blood of the calf.

The long persistence in an animal of the specific serological reaction to *B. abortus* antigen is considered by the Missouri station (*30*) to be dependent on the persistence in the same animal of the living *B. abortus* microorganisms, and that they are present in an excretable condition.

Agglutination tests made simultaneously with blood serum and milk upon all of the cattle in the California station (*31*) dairy herd indicated no direct relation between the agglutinin content of the blood and that of the milk, since a few of the cows positive in blood were not positive in milk, and in most cases where blood and milk both were positive the milk showed a lower titer. In every case where *B. abortus* was isolated from the milk, the milk gave a positive reaction and *B. abortus* could not be isolated from every case in which the milk was positive to the agglutination test. It was

found that agglutinins may be present in the milk in cows that have aborted and in the milk of cows that have never actually aborted. Periodic agglutination tests upon the blood serum identified practically all the "carriers," inasmuch as no cow was positive consistently in the milk and not in the blood, although *B. abortus* was found once in the milk of a cow which had been negative in the blood and milk at every test.

Carriers and transmission.—The cow is apparently most dangerous as a source of infection at the time of calving or aborting. Cows inoculated artificially with *B. abortus* and kept isolated thereafter from other cattle for four years were found by the Missouri station (*32*) still to be carriers of the infection and at the time of parturition were capable of infecting nonreacting pregnant cows through their uterine discharges.

Ingestion has generally been found to be the principal means of transmission of infection. The Connecticut Storrs station, however, concludes (*29, 33*) that transmission by the male is the most important means of spreading the disease. This station (*29*) failed to bring about infection by repeated administration of artificial cultures of *B. abortus* through the mouth, other chances of infection being eliminated. Infection was repeatedly accomplished, however, by painting the urethra with suspensions of *B. abortus* and applying them directly to the vulva. Small laboratory animals, including guinea pigs, rabbits, and mice, proved highly susceptible to infection by *B. abortus* by mouth, vagina, and urethra, as judged by the agglutination and fixation tests and in some cases by the death of the animal (*34*). Infection of calves before the age of 8 or 9 months was found to be extremely rare, and it was demonstrated that the disease is not transmitted from dam to calf (*2*). Observations by the Oregon station (*12, 35*) appear to confirm the findings of other investigators that the organism lives only in the pregnant uterus and the udder and that infection enters the body through ingestion. Observations at this station (*27*) also showed that the animals are most apt to abort during the pregnancy in which the initial infection is received, and that animals infected during their first pregnancies are more apt to abort than those infected during later pregnancies.

Abortion is not inherited, and heifer calves are not infected by drinking infected milk, according to findings of the Oregon station (*12, 27*). The Wisconsin station (*36*) showed the average time required for abortion to result after infection to be about 58 days.

The Connecticut Storrs station (*2*) found that the period of greatest susceptibility to established infection is apparently between the ages of 10 months and 3 years, or from the time of sexual maturity to the first parturition, after which early period the chances of permanent infection rapidly decrease. It was found that few cows changed from negative to positive after the fifth year.

In experiments at the Oregon station (*12, 27*) breeding negative cows and heifers to negative bulls which had served positive cows did not result in infection. Exposure of pregnant cows and heifers in pens or pasture to abortion-infected cows and housing in infected barns were found to be active means of infection. Milk from the udder carrying *B. abortus* was not found by the Michigan station (*40*) to be an important factor in transmission of the disease. The California station (*41*) found the addition of infected cattle to be the manner in which, in the vast majority of cases, the disease is introduced into the herd.

In experiments of the Missouri station (*37*) two of seven heifers from a nonreacting herd bred to a nonreacting bull were fed cultures of the bacillus and aborted, the bacillus being recovered from the fetus. Two others which received injections of the bacillus under the skin developed a positive reaction, but carried their calves to within seven or eight days of maturity, the bacilli being recovered from the placenta, and the milk being positive. Two others, in which the bacilli were injected into the vagina, developed a positive reaction, calved prematurely, and the bacilli were found in the udder; and two in which the bacilli were injected into the teats also calved prematurely. Thus, irrespective of the manner of entry of the germs into the body, they appeared in the udder and uterus. The Missouri station (*30*) concludes that an immune abortion reactor does not as a rule discharge *B. abortus* in dangerous quantity except for a short period coinciding with the last several days of gestation and the cleaning period of approximately four to six weeks following parturition. Experiments with cattle that had been artificially inoculated with the living culture showed that the inoculated cattle continued to react (1) in cases where abortion had occurred following the inoculation, (2) in cases where abor-

tion did not occur, (3) in the case of sterility where the cow was repeatedly bred, and (4) in the case of sterility where ovulation and heat periods were absent. There is a weakening in the virulence of the infection after it has been carried for a number of years by a persistent reactor. On the other hand, the fact that old reactors may lose their resistance and abort, indicates the probability that the abortion infection may regain full virulence and produce disastrous results.

At the Missouri station (*38*) it was found that neither the bull nor the steer are as favorable hosts for *B. abortus* as the mature cow. The Minnesota station (*16*) failed to find as high as 60 per cent of the milk from infected cows to contain *B. abortus*, as has been reported by other investigators.

Pathogenicity of B. abortus.—Strains of *B. abortus* vary markedly in their pathogenicity, as shown by experiments with guinea pigs at the Minnesota station (*16*). Strains isolated from swine are apparently more pathogenic than those from cattle. Records of herds in Oregon (*35*) showed that the disease had apparently not lost its virulence in seven years. The Michigan station (*13*) isolated a number of nonvirulent strains and observed that a majority of them declined in virulence after cultivation for several generations on an artificial medium. There is no rule as to the length of time an aborting cow will carry each succeeding calf, according to the Kentucky station (*39*).

Resistance to infection.—That reacting calves apparently have the power to destroy the infection completely before reaching sexual maturity was indicated by investigations at the Missouri station (*37*). Unbred heifers did not become reinfected by continuous exposure to nonpregnant reacting cows. The mature female host apparently does not have the power to destroy readily and eliminate effectually *B. abortus*, but may remain a permanent carrier. In observations reported by the Connecticut Storrs station (*2*) calves exhibited at birth the same reaction as their dams, and after the sixth and up to the ninth or tenth months were nonreactors and presumably free from the infection. From the ninth to the tenth month was a period of unusual susceptibility to permanent infection. During this period and up to 3 years of age the greatest care is required to combat the spread of infection.

Mastitis and sterility.—There is much more mastitis in infected than in abortion-free cows, according to observations by the Oregon station (*11, 12*). Incurable sterility was shown by the Minnesota station (*28*) to be associated with certain streptococci combined with *B. pyogenes*, and occasionally colon bacilli and staphylococci were involved, *B. abortus* probably preparing the way for other organisms. A large percentage of aborting cows became sterile from closure of the os uteri by fibrous adhesions, usually in connection with a cystic condition of the ovaries, according to the Wyoming station (*42*). In some cases success in breeding followed the rupture of the cysts and breaking down of the adhesions of the os. According to the Wisconsin station (*22*), in the treatment of sterility the autogenous bacterin, if used, must be accompanied by irrigation of the uterus and cervix with a dilute disinfectant such as Lugol's solution, 1 to 400 of boiled water.

Control measures.—The method of eradicating abortion through testing herds, eliminating all reactors, and cleaning and disinfecting the barns has proved successful in case of individual herds in Oregon (*35*). A system of eradication similar to the Bang system of controlling tuberculosis is being tried out, and in one small herd with five reactors there was no spread of infection to sound animals in 15 months, the reacting cows breeding fairly well and calves being raised.

Success in controlling abortion in some herds by removal of the blood-serum reactors is based upon sound scientific data, according to the California station (*43*), and is to be recommended in herds where the infection is not too great. It was found that week-old calves drinking milk artificially infected with *B. abortus* discharged the organism in the feces, and thus may contaminate their surroundings. The blood of these artificially infected calves remained negative to the abortion agglutination test throughout the 37 days that they were fed the abortion organism.

Disinfection of the sheath of the bull and of the vulva and surrounding parts of the female before and after service and dairy barn sanitation are reported to have given good results in control of the disease at the Connecticut Storrs station (*29*). Administration of methylene blue was followed by a somewhat lowered percentage of abortion, in experiments at the Vermont station (*44*). The

disease was eliminated from a herd at the Connecticut Storrs station (*3*) in seven years by selling aborters promptly and by gradual disposal of old reacting cows, but inconclusive results were obtained from the feeding of methylene blue (*2*). Of the various disinfectants tested at the Connecticut Storrs station (*33*), cresol and lysol, which have the same disinfectant value, are preferred, the former being less expensive.

Immunity and immunization.—Abortion vaccine showed a decided immunizing value in experiments at the Wisconsin station (*22, 45, 46*), particularly for cattle of certain groups, such as open cows that had never aborted, and reduced trouble with retained placenta. Vaccinated cattle showed a decrease not only in the abortion rate but in the sterility rate as well. With open cows in infected herds that had never aborted, the vaccine was over 90 per cent effective, as contrasted to about 44 per cent in the control animals. Treating aborting cows with a vaccine gave encouraging results as a means of combating the disease. It is pointed out (*22*) that, since the vaccine is a preparation containing the living germs, it can be safely used only on unbred heifers and open cows at least two months before being bred. It is also stated that the abortion germs have never been known to live in the nonpregnant uterus longer than 58 days.

Negative results were obtained from administration of 20 cubic centimeters of a fresh vaccine prepared at the Indiana station (*47*) by growing *B. abortus* on agar flats for about two days, then washing the growth off with physiological salt solution.

The organism will live for at least two months in a vaccine prepared with a physiologic salt solution and stored in a refrigerator, according to the Wisconsin station (*25*). The Oklahoma station (*15*) found that vaccination may in many instances control the disease. A study of artificial immunity at the Minnesota station (*48*) showed that natural infection does not offer a reliable means for testing the immunizing value of biological agents.

A vaccination experiment at the California station (*49*) demonstrated definitely the protective value of live abortion germ vaccine in the prevention of abortion, and also the ability of *B. abortus* to furnish this protection when given to susceptible animals through the mouth at a single exposure.

The use of vaccine at the Michigan station (*50*) apparently resulted in a decrease in the abortion and sterility rate of the treated animals and a marked increase in the breeding efficiency of the treated over the untreated animals. It was also noted that calves born of treated animals gave negative reactions to the serological tests at birth and were not affected with white scours or other diseases attributed to *B. abortus*.

INFECTIOUS ABORTION OF SWINE

Prevalence.—Abortion has developed into a serious menace to the swine industry, particularly in Wisconsin, Minnesota, and Illinois (*36, 51, 52, 53*). In certain infected herds in Illinois as high as 30 to 40 per cent of the bred sows aborted in initial outbreaks of the disease. In an outbreak in California (*54*), 105 of 140 gilts aborted and none of 60 sows. It was found that *B. abortus* did not live in the normal nongravid uterus of gilts for more than two weeks after being introduced artificially, but persisted as long as four weeks when associated with pyogenic bacteria and the presence of a metritis. The number of abortions observed in herds in Kentucky (*55*) ranged from 5 to 100 per cent.

Relation to bovine abortion.—The Missouri station (*56*) showed that the organisms of bovine and porcine origin correspond in morphology, cultural characters, serological reactions, and pathogenic action on guinea pigs. This station found some experimental and clinical evidence of the susceptibility of swine to the bovine type. The Wisconsin station (*36, 53*) found that the organism of bovine origin did not cause pregnant sows to abort. In experiments at the Michigan station (*57*), pigs were subjected to natural infection by being kept in barn lots with cows known to be carriers and were also fed a suspension of abortion bacteria of bovine origin at periods of from 1 to 15 days without producing abortion. It is concluded that the feeding of infected milk or the association of swine with cattle infected with *B. abortus* should not be considered dangerous as far as the possibility of infecting swine is concerned. That station concludes, however, that infection and expulsion of the premature fetus will take place when an enormous dose of the bovine type is ingested and when swine are injected with living cultures of the

bovine type. In tests carried on over a period of three years, the Arkansas station (*58*) failed to transmit bovine infectious abortion to sows by feeding them milk from infected cows either before or after they became pregnant. Sows were even fed pure cultures of organisms from infected cows, and in no case was the disease transmitted to the sow. On the other hand, when the bovine virus was injected intravenously into sows, abortion resulted in a number of cases. The Illinois station (*51*) states that although it has not been established that swine contract the disease from infected cattle, it appears that cattle are susceptible to abortion bacilli found in swine, and that care should be taken to prevent the disease from being intercommunicated.

Detection.—Blood tests were found by the Wisconsin station (*36*) to be the most satisfactory means of detecting the disease in swine, the agglutination method being preferred.

Transmission and susceptibility.—In experiments at the Wisconsin station (*53*), infection was apparently contracted by ingesting abortion bacilli, but sows appeared to have considerable resistance against abortion bacilli introduced by way of the mouth before they were bred. Intravenous infection before breeding produced abortion in about 75 per cent of the cases under experiment. A boar injected intrapreputially was able to transmit the disease to sows which he covered shortly after receiving the inoculum. The Missouri station (*56*) concludes that nonpregnant as well as pregnant sows may contract the disease. The herd boar is susceptible and may contract the disease by association with infected sows, but whether by copulation or by ingestion has not been established.

The chief mode of transmission of the organism in swine, according to the Missouri station (*56*), is probably through ingestion by healthy pregnant sows of material contaminated with it by the reacting sow at the time of abortion or at the time of farrowing. This station (*59*) found that the minimum age of susceptibility of gilts to active infection with *B. abortus* corresponds closely to the advent of sexual maturity. The Wisconsin station (*53*) concludes that the disease is so much more likely to be introduced into a clean herd by purchase of swine from an infected herd than by feeding dairy products containing bovine abortion germs, that infection from cattle may be practically ignored. This station (*36*) found that the average time required for abortion to result after infection was about 23 days for the sow.

In experiments at the Illinois station (*23*), infectious abortion in swine was induced by the intravenous and subcutaneous injection of abortion bacilli, and also by feeding abortion bacilli isolated from cases of swine abortion. However, artificially infected sows did not abort consistently. The milk of some artificially infected sows was found to contain bacilli, but it is considered that these organisms do not survive in the nursing young to induce active abortion.

It is possible for some sows to become infected by way of the vagina after the uterine seal has formed, according to the Wisconsin station (*60*), but apparently infection by this path after conception has taken place does not occur frequently. Experimental gilts were infected by vaginal introduction of abortion bacilli before pregnancy. The establishment of infection in nonpregnant sows was found to be more difficult than in pregnant ones. Sows become infected most readily per vagina at or near the time of service. Most of the sows and gilts experimentally infected with living abortion bacilli failed to react to the agglutination test after the lapse of four months, indicating that the danger of establishing permanent infection carriers by vaccination is not great. After the subcutaneous and intravenous injection of living abortion bacilli a small percentage of sows and gilts failed to conceive even though served repeatedly.

Immunity.—Abortion in hogs is a self-limiting disease, in that a naturally acquired infection is usually followed by immunity, which will protect some sows for a long period of time, according to the Wisconsin station (*25*). Vaccination experiments at the station justify the belief that it is a means of conferring active immunity and promises to be effective as a means of control (*25, 53*). Subcutaneous and intravenous injection of living abortion bacilli in open sows and gilts apparently resulted in no permanent injury in the majority of cases (*60*). This treatment enabled both open sows and gilts to withstand the effects of large doses of abortion germs after they were bred. The station finds that swine usually, though not always, react to the agglutination test following subcutaneous and intravenous injections of living abortion bacilli. Observations on a herd by the Kentucky station (*61*) indicate that swine do not become resistant

to abortion infection following one abortion as generally believed, but do become resistant after the second and third abortions.

In extended studies by the Missouri station (*59*) of the transmission of the complement-fixing *B. abortus* antibodies it was found to be an almost invariable rule that the blood samples of pigs from abortion-reacting dams were negative if drawn before pigs had sucked the mother and positive if drawn a while after the pigs had sucked. The reaction was of a positive nature, due to the ingestion of colostrum, and disappeared in the course of a few weeks, a minimum period of 18 days and a maximum period of 79 days, with an average of 45 days, having been observed. The age at which gilts exposed to maternal infection showed evidence of a durable positive serological reaction for the specific *B. abortus* antibodies varied from 4½ to 22½ months, the greater number from 6 to 9½ months of age. It was found that the antibody content of the blood fluctuated more in young than in mature swine that become infected, as shown by alternating positive and negative periods. Sexually mature sows, as a rule, retained the abortion infection indefinitely and reacted persistently to the serological tests.

In control work at the Kentucky station (*62*), in which three or four injections of bacterin were made, encouraging results were obtained, which, however, were not conclusive as to its value.

EQUINE INFECTIOUS ABORTION

Abortion in the mare has been investigated at the Kentucky, Minnesota, and Iowa stations. The first (*63*) found the trouble to be due to a member of the colon typhoid group distinct from that in cattle, to which the name *B. abortivo-equinus* was given. A number of Kentucky breeders have immunized their horses with a bacterin discovered and prepared by the station (*64, 65*), and in no instance where it has been used as a prophylactic has the disease occurred. Several hundred mares have been immunized (*66*), with perfect results so far as could be determined, by four doses of the bacterin administered at intervals of seven days. The only apparent disadvantage of this treatment was a stiffness of the muscles in some cases (*64*) which lasted for a day or two.

The Minnesota station (*52, 67*) concludes that hemolytic streptococci are the cause of nearly all the infections of breeding mares and foals in that State. Mares in foal were treated with an autogenous streptococcic bacterin at about the seventh month of pregnancy with very satisfactory results. A study of the action of eight strains of *B. abortivo-equinus* on certain of the carbohydrates has been reported by the Minnesota station (*68*).

The isolation from the foal of an aborting mare of an organism belonging to the abortion Malta fever group and which was apparently *B. abortus* is recorded by McNutt and Murray of the Iowa station (*69*).

ABORTION IN SHEEP

Abortion in sheep and goats is occasionally reported, but in the cases studied by the stations it appears to have been due to other causes than *B. abortus* and is essentially different from the common forms of infectious abortion. An outbreak of abortion among range sheep in Montana in 1923 was found by the station (*70*) to be due to the vibrio described by McFadyean and Stockman, the probable source of infection being a polluted water supply. The disease occurred in enzootic form. The agglutination test appeared to have definite diagnostic value for the disease.

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HISTORY OF STATION WORK IN AGRICULTURAL ECONOMICS

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In connection with the ninth annual meeting of the American Economic Association at Baltimore, Md., in 1897, there was a discussion by such leaders in agricultural, economic, and sociological thought as W. A. Scott, C. S. Walker, L. F. Ward, E. R. A. Seligman, and others of the economic phases of land tenure, mortgage indebtedness and credit, and the movement of population from the farm to the city (*1*).[2] The discussion did not give particular attention to the economics of farm management or of marketing but rather to the maladjustment of agriculture with other industries. This meeting constituted what was probably the first public attention given in the United States to agricultural economics, and its general purpose was to answer the question, "Is there a distinct agricultural question?" This was answered by some of the speakers in the affirmative, by others in the negative. It persisted, however, and in 1903 the subject was again recognized, this time in a joint session held between Section I of the Association for the Advancement of Science and the Society for the Promotion of Agricultural Science (*2*). Among the papers read were Improvement in Farm Management, by W. M. Hays; Economic Functions of Livestock, by C. F. Curtiss; Agricultural Economics, by H. C. Taylor; and The Evolution of Agriculture in the Middle West and Its Social and Economic Significance, by E. Davenport.

In December, 1906, the committee on methods of teaching agriculture of the Association of American Agricultural Colleges and Experiment Stations, in outlining a 4-year college course in agriculture, drew up and published a syllabus of a course in rural economics. In this, rural economics is defined as that subject which treats of agriculture as a means for the production, preservation, and distribution of wealth by the use of land for the growing of plants and animals. It includes the development of agriculture as a business (history of agriculture), as well as the facts and principles of farm management under present conditions (*3*).

In 1907 the first round table on agricultural economics was held during the annual meeting of the American Economic Association under the chairmanship of T. N. Carver (*4*). Those present and participating in the discussion at this time included men interested in the subject from the standpoint of farm management and country life, as well as those who had approached it more largely from the academic field of economics. It was pointed out that the teaching of economic science at the land-grant colleges had been specifically provided for in the second Morrill Act of 1890 (*5*).

At the fourth session of the Graduate School of Agriculture, held at the Iowa State College, Ames, Iowa, July 4–29, 1910, the initial discussion of the field of teaching and investigation in farm management and rural economics and sociology was successfully undertaken, and the American Farm Management Association, now the American Farm Economic Association, was formed, with W. J. Spillman, president; D. H. Otis, vice president; and G. F. Warren, secretary-treasurer (*6*).

Meanwhile research along these lines had been begun, and in this connection it is interesting to recall the remarks of Professor Scott at the meeting in 1897 mentioned above, when he noted the almost complete absence of definite information upon which to base an answer to the question which had been propounded. He stated that in order to inform himself upon actual agricultural conditions he had endeavored to collect accurate information regarding two small sections, one a township in western New York and the other a township in southern Wisconsin. This effort on his part may be regarded as a forerunner of the numerous surveys which have been made in more recent years.

[2] Numbers in parentheses refer to references page 86.

Some historical interest attaches to the fact that estimates of the cost of raising corn, cotton, and other crops appear in reports of the commissioners of agriculture as early as 1849 and 1850. The cost of cultivating and husking 20 acres of corn in Madison County, Ill., was reported in 1870, and estimates for small acreages in Indiana, Ohio, Pennsylvania, and New York are given in the following year. Prompted by inquiries relative to the cost of raising cereals, the United States Department of Agriculture instituted an inquiry covering the average and total cost under several items for individual States, groups of States, and the country as a whole; and a report based on the estimates made by over 28,000 practical farmers, checked by replies received from over 4,000 experts, was published by the division of statistics (*7*). Nebraska station in 1893 published a bulletin on the cost of farm crops in eight fields at the station (*8*). This presented three tables showing the yield and cost per acre of wheat, oats, and rye, corn, and hay, as well as the cost of marketing and the price per bushel on the Lincoln, Nebr., market, the profit per bushel and per acre, and the rate of interest paid on a land valuation of $25 per acre, omitting taxes. N. A. Weston, then a graduate student of economics at the University of Illinois, undertook an inquiry into the cost of raising corn and oats in Illinois in the season of 1896, and a bulletin was published in 1898 (*9*). In this investigation actual expenditures in terms of day labor wherever possible were asked for, as well as the rate of wages per man and per man and team. Over 300 returns were received in reply to the questionnaires sent out to farmers, 274 of which were used in constructing the tables for corn and 170 for oats.

W. M. Hays, of the Minnesota station, was the initiator of actual systematic and sustained field studies in agricultural economics and therefore the pioneer in research along this line. As early as 1894 he was giving his students exercises in the mapping of their own home farms and subsequently planning readjustments and improvements in accordance with the principles of farm management which they had been learning. That he was active in initiating practical cost-accounting studies is evidenced in the report of the Minnesota Agricultural Experiment Station for 1902, where it is noted that—

"On January 1, 1902, this division [agriculture] and the Division of Statistics of the U. S. Department of Agriculture began a cooperative effort to secure data on the cost of growing field crops. Three statisticians were employed for the entire calendar year of 1902: One in southeastern Minnesota, near Northfield; one in southwestern Minnesota, near Marshall; and one in northwestern Minnesota, near Halstad, each with a route about 15 miles long, reaching 12 to 15 farmers. The statistician visited each farmer daily, and recorded where each portion of labor was used. The man hour was taken as the unit and the horse hour as half a unit. Young men suitable for this work were found in the college of agriculture, and very good results have so far been secured. These data will make it possible to make much better application of the results of the field experiments in farm management at the several experiment farms. The data thus gathered, together with the results of experiments in crop rotation by means of field plots added to the pedagogical methods worked out in teaching field management, are demonstrating the value of a union between the experiment station and the college of agriculture. The fact that the farming business can be reduced to a system which may be brought under pedagogical forms and taught in schools of agriculture is a point well worth the expense of demonstration. Many of the young men in the school of agriculture make farm plans as a part of their class work, often remodeling the arrangement of their home farms, which they afterwards report as having been adopted and put into operation at home. The experimental work of the station and the work of the classroom have developed the fact that orderly arrangement may be easily introduced on farms where a wrong system prevails" (*10*).

From simply collecting data on the cost of growing field crops the work developed to include gathering facts concerning produce marketing and the general profits of the entire farm enterprise. In the annual report for 1903–4 it was announced that a bulletin would be published giving the results of investigations in farm statistics and describing the methods developed and the data secured by the three men working in the three areas noted. This made its appearance in October, 1906 (*11*), the first station bulletin to appear in the then com-

paratively new section dealing with the subject of rural economics.

Professor Hays having been appointed in January, 1905, to the position of Assistant Secretary of Agriculture, the division of agriculture at the Minnesota station was somewhat reorganized and the pioneer in agricultural cost accounting in this country carried his work into larger fields, becoming directly responsible for the cost of production studies begun by the United States Department of Agriculture. Cost-accounting routes have been maintained continuously in Minnesota up to the present time with the exception of the years 1918 and 1919 when war conditions necessitated their temporary suspension. The work was renewed January 1, 1920, and two routes of 24 farms each are now being maintained in cooperation with the Bureau of Agricultural Economics, United States Department of Agriculture. This type of work has been adopted from time to time in various parts of the country, until at present 20 States are conducting detailed cost studies either independently or in cooperation with the Bureau of Agricultural Economics (*12*).

Two other stations that have been leaders in research in farm management and agricultural economics are Wisconsin and New York Cornell. In June, 1903, an apple orchard survey in Wayne County, N. Y. (*13*), was begun under the direction of J. Craig by G. F. Warren, then a fellow in agriculture. This was followed by similar studies in other counties in New York, and in May, 1905, an apple orchard survey of Orleans County (*14*) was published. Subsequently, the name of G. F. Warren appeared on the staff of the New York Cornell station, and in his list of cooperative experiments in agronomy in the director's report for 1906, he includes two of an economic nature, the cost and profit or loss in producing crops and the reduction of labor by the use of more horses per man.

In the report of the New York Cornell station for 1908 it is maintained that "the greatest immediate returns for the money invested in this department are secured from the survey work directed (1) to the study of specific crops and (2) to the study of farming as a business" (*15*). The most important work along this line in that year was the agricultural survey of Tompkins County, N. Y. (*16*), of which the field work was practically completed at the time of submitting the report. This survey was actually begun in 1906, and information was collected with regard to a large number of points. The aim of the work was changed in 1907 to that of a farm-management survey to determine the profits for the year on each farm and to find what conditions and types of farms resulted in the largest profit or labor income. The statistics that were finally published, however, were for 1908, because it was not until that year that methods of procedure were so perfected that satisfactory results were obtained. The Tompkins County survey may well be regarded as an epoch-marking contribution to the country-life movement. It was indeed a complete census taking and the first of surveys using statistical methods which had been recommended in the report of President Roosevelt's country life commission in December, 1908.

The report for the year ended September 30, 1908, notes that among other pieces of research work that had been conducted by students and which were worthy of publication was one with reference to the incomes of 194 New York farmers carried on by M. C. Burritt. This study was published in December, 1909 (*17*).

It was not until 1909 that the staff of the Wisconsin Agricultural Experiment Station included a worker in agricultural economics. In the director's report for 1908–9 it is reported that a comparatively new but promising line of inquiry would be organized for the ensuing year, namely, a department of agricultural economics. (*18*). H. C. Taylor, who had been engaged in economic research along agricultural lines in the university, was chosen to head this department, and his work was transferred to the college of agriculture and experiment station. The first bulletin to be published appeared in July, 1910 (*19*). The aims of the various lines of investigation outlined by the new department were the gaining of knowledge of economic forces which influence the farmer in determining what to produce; the kinds and qualities of land, labor, and equipment to use; the degree of intensity of cultivation; the size of the farm; systems of tenure; credit; methods of marketing; and other problems.

The following year it was reported that cost accounting had been successfully carried forward on 15 Wisconsin farms under the supervision of the agricultural economics department of the station in cooperation with the division of farm management of the Bureau of Plant Industry, United States Department of Agriculture. This accounting included an

inventory, financial statement, and man and horse-labor records. Its purpose was to give the farmer a record of the year's operations and of the profits of his business, and also a complete statement of labor and other costs and the results of each line of production which would show him in detail the sources of his profits and losses. It was attempted to indicate the relative profitableness of various competing crops, such as corn, tobacco, and sugar beets, or barley, oats, and spring wheat (*20*).

By 1910 historical and geographical studies were well established and studies of land tenure were being continued with special reference to negro tenure and plantation organization in the Cotton Belt. Farm surveys were being made by D. H. Otis, of the Wisconsin experiment station, who was personally visiting large numbers of farms to secure data with regard to good and bad farm-management practices associated with various types of farming. In the next year, work in cost accounting was begun in cooperation with the Office of Farm Management of the United States Department of Agriculture; also, Professor Otis had gathered data on 103 Wisconsin farms as to the capital in use and the distribution, amount, and sources of farm income and expenditures. Prominent leaders have been developed at this institution in later years in other important phases of the broad subject of agricultural economics, particularly cooperation among farmers and the marketing of agricultural products.

Survey and cost-accounting work has been carried on consistently, once it was fairly outlined and its importance realized, and notable progress has been made. Definitions of and agreement as to terms and the proper interpretation and application of data are problems demanding considerable attention at the present time.

Cooperation with the U. S. Department of Agriculture has greatly strengthened, coordinated, and extended the economic work of the individual stations. Charts prepared by the Bureau of Agricultural Economics, indicating all the regions which had been surveyed in the United States or were represented in published reports of field studies up to and including 1922, show that one or more sections in every State with the possible exception of Nevada, Wyoming, and Tennessee have been the subject of more or less intensive, statistical, analytical study with reference to the economics of some phase or phases of their agriculture (*21*).

In the classified list of projects carried on by the experiment stations, 1922–23, there are listed 186 projects in rural economics. These are arranged under the heads of cost of production and accounting, farm labor, farm organization and management, farmers' cooperative organizations, land settlement, land tenure, land values, marketing, rural credit, rural sociology, and miscellaneous studies. In this list, 37 States are represented by at least one project, while certain States, as Minnesota, Iowa, and New York, report from 12 to 28. Under cost of production and accounting are found 63 and under farm organization and management 36 projects.

These numbers indicate the importance given by the leaders in investigation to the gathering of specific data of a type useful in planning the farm organization, particularly in the choice and combination of enterprises and in increasing efficiency in the conduct of individual enterprises. It is to be expected that more and better economic studies will be carried on along these lines, leading to well-advised programs of action in the adjustment of the individual farming business to changing economic conditions, to better organization among farmers for marketing and distribution, and to furthering economic legislation affecting agriculture.

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STATION WORK ON THE VENTILATION OF ANIMAL SHELTERS

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Considerable interest has developed recently, particularly in the Central, Northern, and Northwestern States, in securing a broader and more fundamental knowledge of the ventilation not only of beef-cattle, dairy-cow, sheep, and horse barns, but also of hog and poultry houses. There are about nine projects either in operation or being planned at as many State experiment stations on one phase or another of the subject or on some closely related subject. There is evidence of an effort to get away from the mere comparative testing of ventilating contrivances and to establish some of the principles governing the operation of such equipment as a basis for its perfection.

The lack of fundamental knowledge of the subject is reflected in the rather scattered record of work conducted by the experiment stations and by foreign institutions, extending back over a period of from 35 to 40 years. As a whole, however, this work indicates clearly the main purpose of ventilation in animal shelters, viz, to supply sufficient fresh air, and to maintain such degrees of air purity, temperature, humidity, and exposure to draft as will provide for the particular animal concerned optimum conditions of health, comfort, and economical production.

The more recent studies have shown an effort to attain a higher degree of scientific accuracy by basing judgment as to the condition of the animal concerned upon expert observations of such factors as weight, body temperature, blood circulation, respiration and metabolism, heat and carbon dioxide emission, rate of growth, activity, food and water consumption, and apparent comfort, as well as egg production and quality in the case of poultry, milk production and quality in the case of dairy cows, and meat production and quality in the case of beef cattle, hogs, and sheep.

AIR SUPPLY AND PURITY

Livestock.—In studies of ventilation factors at the Wisconsin station, King (*1*)[3] showed that the yield of milk, in two experiments with 20 and 25 cows, respectively, was larger in the periods of good ventilation of the dairy barn than in periods of poor ventilation, although there was no appreciable influence upon the quantity of food consumed. In experiments at the Maryland station, Buckley (*2*) demonstrated that the milk records of cows kept in a well-ventilated stable showed a decided increase in yield and that exposure to low temperatures did not necessarily reduce the yield as long as they were natural and constant.

In further studies at the Wisconsin station, King (*3*) found that in order to maintain health and comfort standards, a horse must draw into and force out of his lungs an average of 142 cubic feet of air per hour, a cow 117, a pig about 46, and a sheep about 30. He estimated that the necessary degree of freedom of the air from other gases was not less than 96.7 per cent. Since carbon dioxide produced by the animals in their metabolic processes is the gas most usually occurring in appreciable quantities in air under such circumstances, it was therefore used as an indicator of air purity apparently without reference to its effect other than as a displacer of air. From these figures and from figures obtained for the carbon dioxide contents of pure and expired air it was determined that on an average air must enter and leave a stable at the rate of 4,303 cubic feet per hour for a horse, 3,545 for a cow, 1,394 for a hog, and 909 for a sheep. Using the same basis of air purity, Armsby and Kriss (*4*) found in more controlled studies at the Pennsylvania station that a horse requires 2.307, a cow 3.452, a hog 767, and a sheep 332 cubic feet of air per hour. The figures for cows agree fairly well with those found by King, but those for the other animals vary widely. A very general disagreement also exists between these results and those found by certain foreign investigators.

Determinations of the carbon dioxide content of the air in the dairy barn at the New Hampshire station, made by Hendry and Johnson (*5*) showed that the percentages found at regular intervals during the day and night at 15 different locations in the

[3] Numbers in parentheses refer to references, page 95.

front and rear of the animals varied from 0.228 to 0.089. It is to be noted that the percentages found by the 1918 Farm Building Ventilation Committee of the American Society of Agricultural Engineers (*6*), in studies of five barns, were as high as 1.231 but for the most part were not higher than from 0.2 to 0.3. The importance of a controlled study to determine proper carbon dioxide limits to correspond to the optimum health and comfort of these animals is thus plainly evident.

Poultry.—Apparently few data are available from the experiment stations on the requirements of poultry as regards the supply and purity of air. It may be noted, however, that Mackenzie and Russell (7) found, in controlled studies at the Southeastern Agricultural College, Wye, England, that chickens breathe about a pint of air per minute or 1.2 cubic feet per hour. Further studies (*8*) showed that, although poultry were apparently healthy in the presence of from 6 to 8 volumes of carbon dioxide in 10,000 of air, 9 volumes of carbon dioxide is the maximum permissible air displacement. From this it was estimated that each bird requires 40 cubic feet of air per hour to prevent exceeding this limit of purity and provide a satisfactory factor of safety.

HUMIDITY CONTENT AND TEMPERATURE OF AIR

Where natural systems of ventilation are used, the body heat given off by animals is relied upon to maintain the temperature of the stable or other shelter at a comfortable degree, especially in cold weather, and it also serves as the motive power for ventilation through its control of the air temperature.

Livestock.—Armsby and Kriss (*4*) showed at the Pennsylvania station that the bodies of farm animals during health maintain a nearly constant temperature as the resultant of thermogenesis and of thermolysis principally by radiation and conduction and as latent heat of water vapor. Although the external temperature tends to influence the outflow of bodily heat, the animal is able to regulate it by physical and chemical methods, but there is a certain critical external temperature at which the outflow of heat just balances the necessary heat production of the animal as a result of internal work. Above this temperature the radiating capacity of the body surface varies to meet the varying conditions. Below it, oxidation of tissue is required to maintain the normal temperature of the body. Thus temperature obviously influences feed consumption, productive feeding, and animal comfort.

In experiments at the Wisconsin station King (*1*) found a difference of 6.3° F. in the mean temperature of a dairy stable during periods of good and poor ventilation, and that the cows drank more water during the periods of poor ventilation. In studies at the Massachusetts station with six cows divided into two lots, Brooks (*9*) showed that the apparent influence of a warm stable upon milk and butterfat production was small, although on the average more milk and butterfat were produced in the warm stable. The most certain effect was the lowering of the percentage of the fat in the milk produced in the warm stable. The total increased product did not pay for artificial heating up to 55° F., but the artificial maintenance of a moderate temperature improved ventilation conditions and promoted the comfort of the animals.

In two trials with 12 cows and two with 6 cows conducted in different years at the Wisconsin station by Richards and Jordan (*10*), in which the effect of a stable temperature of about 55° F. was compared with that of one of about 45° upon the milk yield, it was found that on the average all the trials were in favor of the higher temperature. However, in one out of four trials there was a difference in milk yield and in another case a difference in fat content in favor of the lower temperature.

Clarkson and Whitnah (*11*) of the 1920 Barn Ventilation Committee of the American Society of Agricultural Engineers found, in studies of climatic dairy barns, that dairy barn temperatures may vary from 35° to 50° F., according to the climatic zone, but that they should never go below 33°. It was also found that the amount of heat given off by a dairy herd is very nearly constant for cattle of a given size for a given climate.

Armsby, Fries, and Braman (*12*) in studies at the Pennsylvania station established definite relations between the heat produced and carbon dioxide eliminated by cattle and derived mathematical expressions therefor. A comparison of the daily output of carbon dioxide and the heat production by steers and cows for 188 separate days showed that in each case the ratio of the carbon dioxide produced in grams to the total heat emission in calories was very close to 0.4. Armsby and Kriss (*4*) showed that the motive

power for ventilation derived from water vapor is of only secondary importance. They showed further that cows, horses, swine, and sheep of respective average live weights of 1,075, 1,250, 280, and 91 pounds will maintain respective average temperature differences corresponding to air flows computed from carbon dioxide production of 36.58, 36.49, 36.4, and 36.5° F. It is to be noted that the respective temperature differences as computed on the basis of the King standard (*1*) are 35.6, 19.6, 20, and 13.3° F.

Data on the temperature of the stable when air enters at different temperatures showed that when the King standard of air flow is taken as the minimum, the heat supplied by cows appears to become deficient for maintaining what is believed to be the best stable temperature when that outside is below 15° F. The heat supplied by horses, swine, and sheep appears to become deficient at a much higher outside temperature. However, when rate of air flow computed from the carbon dioxide production is made the basis of the computation the differences between the species disappear. Data on the maximum ventilation compatible with the maintenance of a given temperature difference indicated the necessity in severe weather of restricting the ventilation in order to conserve heat and maintain a desirable stable temperature. This was found to result in lowering the purity of the stable air below King's standard. In spite of the fact that the amount of carbon dioxide produced by animals is approximately proportional to their heat production, it was found that the accepted ventilation requirements for different animals are not proportional to their heat production. These results indicate clearly the need for further fundamental and controlled investigations of the temperature, humidity, and air purity requirements of cattle, horses, swine, and sheep, especially in view of the disagreement of many foreign investigators with some of these results.

Poultry.—In feeding experiments with 46 chickens at the North Dakota station, Hinebauch (*13*) showed that when the poultry house was heated about half as much food was consumed and the egg production was more than doubled. The results of two years' experiments at the West Virginia station by Stewart and Atwood (*14*) with floored and unfloored poultry houses showed that the fowls remained in as healthy a condition and laid as many or more eggs in the somewhat warmer unfloored houses as in the floored houses. Studies by Gardiner (*15*) at the Montana station showed that poultry houses may be profitably heated, an average temperature of from 45 to 50° F. being regarded as most satisfactory.

Somewhat in contrast to the above results, Kempster (*16*) found in two years' studies at the Michigan station with three flocks of 70 White Leghorn hens that there was nothing to be gained in egg production by the construction of warmer poultry houses. Opperman (*17*) found in experiments at the Maryland station that fowls kept in colder and less expensive houses gave as high returns as those confined in warmer and more expensive buildings. The general health of the fowls in the different buildings was practically the same during a period of two years, except that the lack of fresh air and the excessive moisture in the warm, tight house caused an absence of bright red combs and the appearance of rough and dirty plumage. The plumage of the fowls in the colder but better ventilated and drier houses was bright and clean.

These results show how investigators disagree regarding the temperature and humidity requirements of poultry and indicate a need for studies of these ventilation factors under controlled conditions.

MECHANICS OF VENTILATION

In spite of the obvious lack of accurate fundamental knowledge regarding the ventilation requirements of farm livestock and poultry, considerable work has been done at the experiment stations and other institutions on the mechanics of ventilation systems for specific purposes.

In this work the best possible use has apparently been made of the admittedly inadequate basic data available in an attempt to develop ventilation systems specifically adapted to the requirements of the animals as far as these were known.

Livestock shelters.—On the basis of his studies at the Wisconsin station of the ventilation requirements of livestock, King developed a system of ventilation for livestock shelters which was very generally adopted for a number of years. This system was incorporated in the new dairy barn at the station by Carlyle (*18*). It comprised a single ventilating flue rising above the roof of the main barn and divided below the roof into two arms terminating near the level of the stable

floor. These openings were provided with ordinary registers with valves to be opened and closed when desired. Other ventilators were available for temperature regulation. This system was also incorporated in the barns of several of the stations in original or modified form (*19, 20, 21, 22*).

More recently it has been found that climatic and other conditions, as well as animal requirements, have considerable influence upon the type of ventilation system best adapted to a given purpose. The extreme variations in these have led to material modification of the King system and to the development of new systems, particularly in some of the neighboring Canadian Provinces.

For example, Reynolds (*23*), in experiments at the Ontario Agricultural College, developed a system of ventilation of stables by means of pipes extending to the floor of the stable and terminating at the peak of the roof in revolving cowls. The pipes were so arranged that the air entered for the most part at the floor in front of the stalls, and the foul air passed out by means of pipes leading from the ceiling of the stable to the barn roof.

Experiments by Grisdale at the Canada Experimental Farms (*24*) demonstrated the superiority of the so-called Rutherford system of stable ventilation, the essential feature of which is an arrangement whereby fresh air enters at the floor level and leaves through a flue extending from the ceiling to the roof. A modification of the King system also proved satisfactory. Experiments with the covering of stable windows with muslin when the outside temperature varied from 2° to 36° F. and the inside from 36° to 62° were unsuccessful, owing to the extreme range of resulting inside temperatures and the dampness of the air. Comparative tests conducted by Day (*25*) at the Ontario Agricultural College on muslin-curtain ventilation, the King, and the so-called Massey systems, showed that the muslin-curtain system is unreliable and inferior to either of the other systems, especially in view of the irregular distribution of carbon dioxide and moisture. The Massey system is based upon the same general principle as the Rutherford system, but varies in structural detail. Further studies by Grisdale and Archibald (*26*) at the Canada Experimental Farms demonstrated the superiority of the Rutherford system over the King system for horse and cow stalls and hog houses. Smith (*27*) obtained similar results in studies at the Manitoba Agricultural College and concluded that the Rutherford system is superior to all others for Canadian Northwest conditions. However, further studies by Smith (*28*) showed that either the King or Rutherford system can be used in banked barns or in barns having stone, brick, or concrete walls, but that the cubic space allowed should be less than 600 cubic feet per animal for cattle and less than 750 cubic feet per animal for horses.

Studies on climatic dairy barns by Clarkson and Whitnah (*11*) showed that a barn ventilating system makes the most efficient use of the heat given off by cattle by drawing the foul air from near the floor. The necessity was demonstrated of so constructing the walls that the heat losses through them will be small enough to leave the heat required for proper ventilation. Barn walls in the first climatic zone, where temperatures will drop as low as —30° F., should have a coefficient of heat loss not greater than 16 B. t. u. per hour per degree difference in temperature.

Experiments by Smith (*29*) at the Brandon Experiment Station in Manitoba showed that an average ventilation of 4,590 cubic feet per hour per cow obtained by the Rutherford system in a barn containing 67 cows and allowing 700 cubic feet of space per cow and 120 cubic feet of air to be breathed per hour per cow gave an air purity of 97.36 per cent. Decreasing the outtake flue area decreased the temperature fall inside as the outside temperature fell steadily, and finally caused an increase in the inside temperature without lowering the air purity below 95 per cent.

Experiments by Clarkson and Whitnah (*30*) on the proper relations between heat, light, and ventilation in hog houses showed that heat losses under first climatic zone conditions were least from (1) a 2-story building with overhead storage, (2) a 1-story building with a flat pitch gambrel roof and a ceiling extending across from one hip of the roof to the other, and (3) a 1-story building with a flat pitch gambrel roof and an inclined ceiling on each side extending from the hip of the roof down to the girders and across between the girders. The greatest heat losses occurred from a full monitor roof type and a shed roof type. Heat losses were also greater through skylights than through vertical windows.

Patty of the South Dakota station (*31*), found that, with over 1,200 cubic feet of air circulating through a hog house 80 by 28 feet in size and with low side walls and low overhead space, the air was changed completely every 16 minutes; but the temperature remained practically constant, although the outside temperature dropped from 4° to 5°. There was no excess moisture in the air, and the suction effect of the aerators on top was not necessary to maintain air circulation.

In studies of the factors influencing the operation of dairy barn ventilation systems, with particular reference to forced draft, Kelley (*32*) of the U. S. Department of Agriculture showed that, on the basis of the data obtained by Armsby (*4*) for dairy cows, as the total heat lost by ventilation and radiation decreased the temperature inside increased. On the basis of the heat production estimated from the individual weight of each cow, the results showed that with the fan system of ventilation used 43.7 per cent of the heat generated by the animals was lost by ventilation and 23.5 per cent by radiation.

In considering the design of outtake flues for dairy barn ventilation with a natural draft system on the basis of the heat and carbon dioxide production of dairy cows, Strahan (*33*), of the Massachusetts station, showed that different breeds of dairy cows introduced different conditions to be met. It was considered reasonable to expect Holsteins to maintain in zero weather a temperature above freezing in a stable 36 by 80 feet inside and housing 40 cows, and at the same time to maintain adequate ventilation conditions. On the other hand, it was shown that, if Jerseys in low production are housed, the stable temperature will drop below 32° F. as soon as the outside temperature goes below 6°, if the same rate of air flow is maintained through the stable. Under these conditions the air flow would have to be reduced over 1,200 cubic feet per cow in order to keep the inside temperature up, which would tend to lower the ventilation standard considerably. It was further shown that small Jersey cows on maintenance alone can maintain a temperature difference of from 15° to 17° in well-constructed stables, and it was considered correct to assume that outtake flues may be designed to pass the required amount of air through a stable at a minimum temperature difference of 20°. Armsby (*4*) also brought out that different breeds of dairy cows produce different amounts of carbon dioxide and heat.

In further studies in cooperation with several of the experiment stations, Kelley (*34*) showed that the factors influencing the maintenance of the desired temperatures in animal shelters are insulation, tightness of construction, air space each animal is expected to heat, and the desired amount of ventilation in accordance with the type of animal housed. No definite relation was established between the velocity of the wind and the effect which it has in the production of draft in a well-designed ventilating system. It was noted that in barns using wall intakes the wind sometimes had a greater influence upon the air going out than upon that coming in. The design and position of the intakes were found to influence back drafting and its velocity. The lowest wind velocity which produced back drafting in wall intakes 5 feet or more in length was 6 miles per hour. Window intakes were unreliable, made the control of the stable temperatures difficult, and permitted the wind velocity to exert a greater influence upon the amount of ventilation.

Under average conditions a greater difference was found between the ceiling and floor temperatures in horse stables than in dairy stables. Openings near the floor in outtakes appeared more favorable to the maintenance of stable temperatures than ceiling openings, especially during cold weather.

In further studies of hog-house ventilation conducted at several of the experiment stations (*35*), Kelley showed the possibility of maintaining a reasonably uniform temperature in a barn housing a total weight of 26,775 pounds of hogs by regulating the amount of intake openings.

Poultry houses.—Almost every experiment station has conducted a study of one or more phases of the poultry-house question. However, few have made a comprehensive study of the construction of poultry houses based upon the ventilation requirements of the poultry. There are a few exceptions to this, although practically no work of an entirely controlled nature is on record.

In experiments at the New Jersey stations, Lewis and Clark (*36*) showed that, under New Jersey conditions, a poultry house with a large area of glass and no muslin had a high moisture content and low temperature accompanied by rapid changes, whereas

an open-front house furnished ideal ventilation conditions, provided the birds were protected from rain, snow, and drafts. It was possible, however, to use some glass and muslin in the front. Provision of ample ventilation for shed-roof paper-covered houses was found to add greatly in reducing the temperature during spring and summer. In experiments at the Connecticut Storrs station, Jones and Card (*37*) demonstrated the effectiveness of a curtain of unbleached muslin in allowing fresh air to pass in and moist foul air to pass out of a poultry house without submitting the chickens to drafts. Similar results were obtained by Kempster (*38*) at the Missouri station. He also found that 1 square foot of muslin should be placed on the south side of the poultry house for every 15 square feet of floor space if the house is 15 feet wide, for every 20 square feet if the house is 10 feet wide, and for every 10 square feet if the house is 20 feet wide. The height of the tops of windows on the south side should be a little less than one-half the width of the house.

Experiments at the Minnesota station (*39*) showed that the average temperatures in poultry houses were lower with muslin fronts than with glass fronts. Schoppe (*40*) found in experiments at the Montana station that the combination curtain and glass-front house was extremely satisfactory in many sections of the State. It provided better ventilation and more sunshine than the open-front house with no glass and did not expose the birds to draft. A wide house was found to be better than a narrow one, since it placed the roosts farther from the openings in the front and the birds were less affected by outside changes in temperature. It was found advisable to sheathe houses on the inside to afford extra protection during extreme weather and to sheathe them overhead to cut down the air space as much as possible.

In a two-season study at the New Jersey stations of winter and summer temperatures and humidities in six different types of poultry houses, Lewis and Thompson (*41*) showed that in order to be efficient the average poultry house should be warmer than the outside normal temperature in winter and cooler than the outside normal temperature in the summer, with the difference somewhat greater in the winter than in the summer. The use of solid glass sash in the poultry house with no adequate means of continuous ventilation was found to be conducive to frozen combs and cold. An increase in height of the poultry house also made it colder. The use of some muslin and some glass improved matters for shed-roof types, and during the winter a shed-roof frame laying house divided into four pens and having a hinged clapboard on the outside of the back wall for ventilation and a concrete floor and foundation, was the warmest and driest. A half-monitor house with entire glass front in the peak and elevated about 2 feet from the ground was exceptionally cold and damp. During the summer a shed-roof type built entirely of lumber was the coolest.

METHODS OF STUDY

Most of the studies on the ventilation of animal shelters at the stations have been conducted in service barns and houses. An estimate has usually been made of the values of the important ventilation factors corresponding to the best health and comfort of the animals, an arbitrarily chosen system of ventilation has been installed, and observations of the values of the ventilation factors made as well as possible under variable conditions of weather and the extremely variable conditions of the animals themselves, these to be used as a basis for modification of the ventilation system until satisfactory.

However, attempts have been made in certain cases to introduce at least partial control in some of these studies. For example, Armsby (*42*) attempted to control his studies of the health and comfort requirements of animals and of the corresponding ventilation factors by the use of a respiration calorimeter. By this means he was able to study heat and food values (*43*), with particular reference to the nature, amount, and rate at which heat is produced by the animal body. Armsby (*44*) finally developed a calorimeter at the Pennsylvania station adapted to livestock, from which he was able to deduce the most recent and apparently most reliable data on heat production, air purity and humidity, and natural ventilation motivation with reference to cattle, horses, sheep, and swine (*4*). Benedict and his coworkers at the New Hampshire station (*45*) have also devised an apparatus for quickly and conveniently measuring the amount of carbon dioxide eliminated by large domestic animals.

A similarly comprehensive method of procedure is being planned at the Iowa station in studies of poultry-house ventilation to determine the amounts and rates of ventilation corresponding to the optimum values of the ventilation factors under Iowa conditions and to design ventilation systems accordingly.

Since controlled studies of this nature involve heat losses through building materials, it is of interest to note that Cumings (*46*) has recently conducted studies at the Colorado station on heat losses through commercial wall board, which showed that the average coefficient of heat transmission varied for the different types from 0.73 to 1.01. Four types of wall board had coefficients varying from 0.78 to 0.81.

CONCLUSION

It seems very generally agreed that a rather fine balance must exist between temperature, humidity, air purity, and amount and rate of ventilation in livestock and poultry shelters in order to insure optimum conditions of health, comfort, and economical production in the animal or fowl. It is therefore important to plan and conduct ventilation studies so as to definitely establish the proper proportions of these factors for different species of animal under different ranges of climatic conditions.

To be of value for this purpose the studies must be conducted under absolutely controlled conditions. Enough work has been done to demonstrate the futility of attempting to standardize the important ventilation factors until methods and apparatus are available which will introduce a control of animal body processes and ventilation factors equivalent to that in respiration calorimetric investigations.

Obviously such studies should be begun with animals already in the optimum of condition, as judged by suitable standards, and an effort should be made to maintain this optimum. Observations made of ventilation factors during such a procedure should yield optimum values therefor and should provide the soundest possible basis for the design of systems to supply the indicated necessary amounts and rates of ventilation.

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INSULAR EXPERIMENT STATIONS

The agricultural experiment stations in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands of the United States were maintained as in previous years, through appropriations made directly to the United States Department of Agriculture as follows: Alaska, $75,000; Hawaii, $50,000; Porto Rico, $50,000; Guam, $15,000; and Virgin Islands, $20,000. These appropriations were the same as they have been since 1920, except that that for Guam was reduced $10,000. The provisions of the Hatch and Adams Acts do not apply to these stations.

The work and expenditures of the stations were supervised as heretofore by the Office of Experiment Stations through Walter H. Evans, Chief of Insular Stations. Statistics relating to the stations are reported on pages 114–117. The results of their work are reported in separate publications.

Few changes were made in the personnel or projects of the stations during the year. All of the projects, however, were reviewed and some were suspended or terminated in an effort to concentrate on the more pressing problems. Most of the projects are planned to bring about a diversified agriculture. Fundamental problems are by no means neglected, but considerable work must of necessity be done in adapting the results of experimentation in other regions to the conditions found in Alaska and the Tropics.

The Smith-Lever Extension Act has not yet been extended to these stations. They have therefore been compelled to do some extension work. In Alaska surveys were made during the summer of 1922 of some of the principal valleys to learn their problems and to furnish a basis for advising settlers as to the practices best adapted to the local conditions. In Hawaii a special effort has been made to reach the younger people, and many boys' and girls' clubs have been formed on the principal islands. This work has been taken up enthusiastically and is meeting with much success. In Porto Rico the Insular Government has recently taken over most of the extension work and the station now acts merely in an advisory and educational capacity. In Guam and the Virgin Islands the stations are doing as much extension work as their limited funds and personnel will permit without detriment to other important work of the stations. In both of these regions there is need for more work of this character, as the people are not able unaided to put into practice the results of the station experiments.

All of the stations are in need of additional funds to develop their work and utilize their equipment to the best advantage, and to extend the practical use of the experimental results.

PUBLICATIONS OF THE EXPERIMENT STATIONS DURING THE FISCAL YEAR 1923

BACTERIOLOGY—BOTANY—CHEMISTRY

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The determination of biologic forms of *Puccinia graminis* on *Triticum* spp. E. C. Stakman and M. N. Levine. (Minn. Sta. Tech. Bul. 8, pp. 10, fig. 1. July, 1922.)

The effect of hydrogen ion concentration upon the growth of seedlings. L. W. Tarr and S. C. Noble. (Del. Sta. Bul. 131, pp. 52, figs. 11. June, 1922.)

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Meteorological observations at the Massachusetts Agricultural Experiment Station. J. E. Ostrander et al. (Mass. Sta. Met. Buls. 402–413, pp. 4 each. June, 1922–May, 1923.)

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SOILS

The reaction of soils in the field as influenced by the long-continued use of fertilizer chemicals. P. S. Burgess. (R. I. Sta. Bul. 189, pp. 35. Apr., 1922.)

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SMALL FRUIT

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Circ. 151, pp. 3, fig. 1. Feb., 1923.)
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DISEASES OF PLANTS

FIELD CROP DISEASES

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Inspection of commercial fertilizers. H. D. Haskins, L. S. Walker, and R. W. Swift. (Mass. Sta. Control Ser. Bul. 20, pp. 42. Nov., 1922.)

Inspection of lime products used in agriculture. H. D. Haskins, L. S. Walker, and R. W. Swift. (Mass. Sta. Control Ser. Bul. 21, pp. 7, fig. 1. Nov., 1922.)

Testing fertilizers for Missouri farmers, 1922. L. D. Haigh. (Mo. Sta. Bul. 200, pp. 51, fig. 1. Feb. 1923.)

Inspection of commercial fertilizers for 1922. H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (N. H. Sta. Bul. 206, pp. 16. Oct., 1922.)

Fertilizer inspections in New Jersey from 1880 to 1921. C. S. Cathcart. (N. J. Stas. Bul. 368, pp. 24, figs. 6. Apr., 1922.)

Analyses of commercial fertilizers, fertilizer supplies and home mixtures. C. S. Cathcart. (N. J. Stas. Bul. 371, pp. 35, fig. 1. Nov., 1922.)

Analyses of commercial fertilizers and ground bone; analyses of agricultural lime, 1922. C. S. Cathcart. (N. J. Stas. Bul. 376, pp. 54, fig. 1. Dec., 1922.)

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Composition and prices of commercial fertilizers in New York in 1922. L. L. Van Slyke. (N. Y. State Sta. Bul. 499, pp. 12. Mar., 1923.)

Commercial fertilizers. R. H. Robinson. (Oreg. Sta. Circ. 31, pp. 16. Nov., 1922.)

Inspection of fertilizers. P. S. Burgess. (R. I. Sta. Ann. Fert. Circ., 1922, pp. 14. Oct., 1922.)

Analyses of commercial fertilizers. R. N. Brackett and H. M. Stackhouse. (S. C. Sta. Bul. 212, pp. 43. Aug., 1922.)

Commercial fertilizers in 1921–1922. G. S. Fraps and S. E. Asbury. (Tex. Sta. Bul. 298, pp. 23. Aug., 1922.)

REGULATORY PUBLICATIONS—FEEDING STUFFS

Report on commercial feeding stuffs. E. M. Bailey. (Conn. State Sta. Bul. 238, pp. 329–361. Feb., 1922.)

Commercial feeding stuffs, 1921–22. J. M. Bartlett. Me. Sta. Off. Insp. 104, pp. 26–43. Aug., 1922.)

Inspection of commercial feedstuffs. P. H. Smith and E. M. Bradley. (Mass. Sta. Control Ser. Bul. 19, pp. 34. Nov., 1922.)

Inspection of commercial feeding stuffs. H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (N. H. Sta. Bul. 205, pp. 51. Aug., 1922.)

Analyses of commercial feeding stuffs and registration for 1922 C. S. Cathcart. (N. J. Stas. Bul. 369, pp. 70. Apr., 1922.)

Inspection of commercial feeds. P. H. Wessels. (R. I. Sta. Ann. Feed Circ., 1922, pp. 16. Apr., 1922.)

Inspection of feeds. P. S. Burgess and J. B. Smith. (R. I. Sta. Ann. Feed Circ., 1923, pp. 12. Apr., 1923.)

Comercial feeding stuffs. B. Youngblood. (Tex. Sta. Bul. 303, pp. 192. Oct. 1922.)

REGULATORY PUBLICATIONS—FOODS AND DRUGS

Twenty-sixth report on food products and fourteenth report on drug products. E. M. Bailey. (Conn. State Sta. Bul 236, pp. 227–300. Jan., 1922.)

Twenty-seventh report on food products and fifteenth report on drug products. Part I. E. M. Bailey. (Conn. State Sta. Bul. 240, pp. 51, figs. 21, Aug., 1922.)

Foods and drugs. J. M. Bartlett. (Me. Sta. Off. Insp. 103, pp. 34. Apr., 1922.)

REGULATORY PUBLICATIONS—SEEDS

Inspection of agricultural seeds. E. G. Proulx et al. (Ind. Sta. Bul. 264, pp 56, fig. 1. Jan., 1923.)

Commercial agricultural seeds, 1922, compiled by W. J. Morse. Insecticides and fungicides, 1922, J. M. Bartlett. (Me. Sta. Off. Insp. 106, pp. 77–99. Dec., 1922.)

Work of the seed inspection laboratory for the year 1921. F. S. Holmes. (Md. Sta. Bul. 249, pp. 189–206. June, 1922.)

Results of seed tests for 1922. M. G. Eastman. (N. H. Sta. Bul. 207, pp. 16 Dec., 1922.)

REGULATORY PUBLICATIONS—MISCELLANEOUS

Commercial fertilizers, commercial feeding stuffs, agricultural seed. J. L. Hills et al. (Vt. Sta. Bul. 228, pp. 32. Sept., 1922.)

Report on commercial insecticides and fungicides. E. M. Bailey, R. E. Andrew, and W. E. Britton. (Conn. State Sta. Bul. 242, pp. 145–165. Nov., 1922.)

Analyses of materials sold as insecticides and fungicides during 1922. C. S. Cathcart and R. L. Willis. (N. J. Stas. Bul. 372, pp. 24. Oct., 1922.)

Eighth annual report of the dairy department creamery license division. R. L. Hammond. (Ind. Sta. Circ. 107, pp. 16, figs. 2. June, 1922.)

Report of the creamery license section, 1918–22. P. E. Bacon. (Ky. Sta. Reg. Ser. 3, pp. 15, fig. 1. Dec., 1922.)

Creamery inspection in New Jersey.—Third annual report. F. C. Button. (N. J. Stas. Circ. 143, pp. 16, figs. 2. June, 1922.)

Eighth report of the Montana grain inspection laboratory. (Mont. Sta. Bul. 149, pp. 24, fig. 1. Nov., 1922.)

The purpose and work of the Montana grain inspection laboratory. W. O. Whitcomb. (Mont. Sta. Circ. 108, pp. 11. Oct., 1922.)

Stallion enrollment.—XI, Report of stallion enrollment work for the year 1922, with lists of stallions and jacks enrolled. (Ind. Sta. Circ. 108, pp. 56, fig. 1. Dec., 1922.)

PUBLICATION LISTS AND MISCELLANEOUS

Periodicals available for reference. (N. Y. State Sta. Circ. 59, pp. 18. [1922.])

Available bulletins. (N. Y. State Sta. Circ. 62, pp. 4. [1922.])

Proposed program of development. (N. Y. State Sta. Circ. 60, pp. 7. [1922.])

List of projects under investigation. (N. Y. State Sta. Circ. 61, pp. 4. [1922.])

Bulletin summary. (Mass Sta. Circ. 68, pp. 6. Apr., 1922.)

Bulletin summary. (Mass. Sta. Circ. 69, pp. 6. Oct., 1922.)

Bulletin summary. (Mass. Sta. Circ. 70, pp. 3. Apr., [1923].)

STATISTICS OF THE STATIONS

By J. I. Schulte

For the fiscal year ended June 30, 1923, the total income from all sources reported by the experiment stations was $9,493,653.20, this amount including $1,440,000 Federal funds under the Hatch and Adams Acts and $210,000 appropriated by the Federal Government for the experiment stations in Alaska and the insular possessions. The support received by the stations from within the States included $5,539,077.02 derived from State appropriations or apportionments, $373,977 from fees, $1,050,238.55 from the sale of farm and other products, $112,415.12 from miscellaneous sources and $767,945.51 carried over as balances from the previous year.

The value of additions to the equipment of the stations during the year was reported as follows:

Buildings	$928,092.82
Library	30,381.50
Apparatus	101,025.75
Farm implements	130,908.35
Livestock	120,988.85
Miscellaneous	148,165.61
Total	1,459,562.88

In the work of administration and inquiry the experiment stations employed 2,259 persons. Of these 1,121 were also members of the teaching staffs of the colleges and 462 assisted in the various lines of extension work. During the year the stations issued 920 publications, including annual reports, bulletins, circulars, and press bulletins aggregating 24,687 pages. These were distributed to 875,056 addresses on regular mailing lists in addition to the number sent in response to special requests. During the past few years the stations have revised their mailing lists, reducing to some extent the total number of names but making the distribution more effective.

The statistics of the stations by States are given in the tables following.

General statistics, 1923

Station	Location	Director	Date of original organization	Date of organization under Hatch Act	Number on staff	Number of teachers on staff	Number of persons on staff who assist in extension work	Publications during fiscal year 1922–23		Number of names on mailing list
								Number	Pages	
Alabama (College)	Auburn	D. T. Gray	Feb. —, 1883	Feb. 24, 1888	24	11	5	4	122	1,700
Alabama (Canebrake)	Uniontown	W. A. Cammack	Jan. 1, 1886	Apr. 1, 1888						
Alabama	Tuskegee Institute	G. W. Carver	Feb. 15, 1897		4	3				
Alaska	Sitka	C. C. Georgeson			8			1	58	
Arizona	Tucson	J. J. Thornber		—— —, 1889	26	21	4	12	290	5,000
Arkansas	Fayetteville	Bradford Knapp		—— —, 1887	27	20	1	7	298	12,718
California	Berkeley	C. M. Haring	—— —, 1875	Mar. —, 1888	146	103	82	53	2,446	40,073
Colorado	Fort Collins	C. P. Gillette		Feb. 29, 1888	41	21	10	10	290	2,900
Connecticut (State)	New Haven	W. L. Slate, jr	Oct. 1, 1875	May 18, 1887	24	1		12	582	9,912
Connecticut (Storrs)	Storrs	do		do	12	6		7	235	8,500
Delaware	Newark	C. A. McCue		Feb. 21, 1888	15	10	3	4	134	7,500
Florida	Gainesville	Wilmon Newell		—— —, 1888	16	1	1	10	213	25,000
Georgia	Experiment	H. P. Stuckey	Feb. 18, 1888	July 1, 1889	7			32	35	6,500
Guam	Guam	C. W. Edwards			4			4	113	
Hawaii	Honolulu	J. M. Westgate			7			1	24	
Idaho	Moscow	E. J. Iddings		Feb. 26, 1892	36	20	8	8	152	15,321
Illinois	Urbana	H. W. Mumford		Mar. 21, 1888	111	70	30	24	412	20,000
Indiana	Lafayette	G. I. Christie	—— —, 1885	Jan. —, 1888	75	20		21	138	35,423
Iowa	Ames	C. F. Curtiss		Feb. 17, 1888	82	24	1	37	1,221	30,022
Kansas	Manhattan	F. D. Farrell		Feb. 8, 1888	85	40		11	416	12,000
Kentucky	Lexington	T. P. Cooper	Sept. —, 1885	Apr. —, 1888	60	23	7	8	440	10,000
Louisiana (Sugar)	New Orleans	W. R. Dodson	do							
Louisiana (State)	Baton Rouge	do	Apr. —, 1886		23	2	9	1	20	8,000
Louisiana (North)	Calhoun	do	May —, 1887							
Maine	Orono	W. J. Morse	Mar. —, 1885	Oct. 1, 1887	15			10	251	19,951
Maryland	College Park	H. J. Patterson	—— —, 1888	Apr. —, 1888	28	14		7	105	16,000
Massachusetts	Amherst [1]	S. B. Haskell	—— —, 1882	Mar. 2, 1888	51	19		29	430	16,000
Michigan	East Lansing	R. S. Shaw		Feb. 26, 1888	71	29	16	21	551	42,000
Minnesota	University Farm, St. Paul.	W. C. Coffey	Mar. 7, 1885	—— —, 1888	115	96	84	19	936	13,000
Mississippi	Agricultural College	J. E. Ricks		Jan. 27, 1888	36	13	1	15	304	16,000
Missouri (College)	Columbia	F. B. Mumford		Jan. —, 1888	57	51		75	1,218	5,834
Missouri (Fruit)	Mountain Grove	F. W. Faurot	Feb. 1, 1900		5					
Montana	Bozeman	F. B. Linfield		July 1, 1893	40	19	6	23	480	6,000
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	41	17		19	606	9,390
Nevada	Reno	S. B. Doten		Dec. —, 1887	8	2		4	92	4,270
New Hampshire	Durham	J. C. Kendall	—— —, 1886	Aug. 4, 1887	23	19	17	10	273	6,568
New Jersey (State)	New Brunswick	J. G. Lipman	Mar. 10, 1880		57	21	22	69	1,996	12,321
New Jersey (College)	New Brunswick	do		Apr. 26, 1888	22					

New Mexico	Agricultural College	Fabian Garcia		Dec. 14, 1889	20	14	2	28	245	10,000
New York (State)	Geneva	R. W. Thatcher	Mar. —, 1882		44			23	434	22,875
New York (Cornell)	Ithaca	A. R. Mann	—— —, 1879	Apr. —, 1888	75	75	12	21	1,624	3,000
North Carolina	West Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	45	3	2	6	132	33,710
North Dakota	Agricultural College	P. F. Trowbridge		Mar. —, 1890	38	11		5	304	8,500
Ohio	Wooster	C. G. Williams	Apr. 25, 1882	Apr. 2, 1888	63			118	2,938	71,590
Oklahoma	Stillwater	C. T. Dowell		Dec. 25, 1890	23	20		11	135	17,825
Oregon	Corvallis	J. T. Jardine		July —, 1888	53	30		29	478	1,456
Pennsylvania	State College	R. L. Watts		June 30, 1887	71	71	50	7	164	44,000
Pennsylvania (Nutrition)	do	E. B. Forbes	—— —, 1907		7					
Porto Rico	Mayaguez	D. W. May			9			3	55	
Rhode Island	Kingston	B. L. Hartwell		July 30, 1888	15	2		6	161	2,000
South Carolina	Clemson College	H. W. Barre		Jan. —, 1888	28	10	7	5	147	5,000
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	18	16		5	144	20,000
Tennessee	Knoxville	H. A. Morgan	June 8, 1882	Aug. 4, 1887	26	1		8	188	12,222
Texas	College Station	B. Youngblood		Apr. 3, 1889	55	1		18	1,102	72,000
Utah	Logan	William Peterson		—— —, 1890	34	31	18	13	204	7,200
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	13	8	2	6	208	6,150
Virginia	Blacksburg	A. W. Drinkard, jr	—— —, 1888	—— —, 1891	32	11	3	5	73	12,000
Virgin Islands	St. Croix	J. B. Thompson			2			2	55	
Washington	Pullman	E. C. Johnson		—— —, 1891	41	11		10	331	11,550
West Virginia	Morgantown	H. G. Knight		June 11, 1888	31	26	3	5	100	26,000
Wisconsin	Madison	H. L. Russell	—— —, 1883	—— —, 1887	98	75	55	11	412	62,076
Wyoming	Laramie	A. D. Faville		Mar. 1, 1891	16	9	1	7	172	8,000
Total					2,259	1,121	462	920	24,687	875,057

[1] In 1882 the State organized a station here and maintained it until June 18, 1895, when it was combined with the Hatch Station at the same place.

Revenue and additions

Station	Revenue						
	Federal		State	Balances[1] from previous year	Fees	Sales	Miscellaneous
	Hatch fund	Adams fund					
Alabama	$15,000.00	$15,000.00	$34,500.00	$7,613.01		$3,732.07	$2,035.00
Alaska							[2]75,000.00
Arizona	15,000.00	15,000.00	88,171.45	695.87		1,699.33	
Arkansas	15,000.00	15,000.00	56,907.64			20,000.00	
California	15,000.00	15,000.00	558,996.60	1,762.98	$11,024.44	99,342.71	25,872.34
Colorado	15,000.00	15,000.00	125,372.79	15,522.14	12,000.00		
Connecticut (State)	7,500.00	7,500.00	62,537.63	6,928.31	12,000.00		8,526.08
Connecticut (Storrs)	7,500.00	7,500.00	19,500.00	2,676.54			16,261.12
Delaware	15,000.00	15,000.00	20,000.00			10,336.09	
Florida	15,000.00	15,000.00	55,000.00	23,871.24		6,023.79	
Georgia	15,000.00	15,000.00	6,813.35	1,497.25		14,588.34	
Guam							[2]15,000.00
Hawaii							[2]50,000.00
Idaho	15,000.00	15,000.00	17,458.48	1,210.10		6,859.09	
Illinois	15,000.00	15,000.00	334,666.68	15,578.81		41,319.33	
Indiana	15,000.00	15,000.00	238,991.38	96,711.10	139,354.87	118,420.88	
Iowa	15,000.00	15,000.00	250,000.00	52,294.89		40,869.59	16.66
Kansas	15,000.00	15,000.00	94,636.35	8,770.96		33,792.38	
Kentucky	15,000.00	15,000.00	50,000.00	19,642.84	49,202.48	35,681.57	5,000.00
Louisiana	15,000.00	15,000.00	56,637.45		25,889.84		
Maine	15,000.00	15,000.00	23,908.25		11,891.96	1,645.59	
Maryland	15,000.00	15,000.00	61,570.32	1,177.36		9,844.57	
Massachusetts	15,000.00	15,000.00	107,410.38		37,522.41	3,983.10	424.39
Michigan	15,000.00	15,000.00	180,000.00	103,376.23		7,063.50	5,314.89
Minnesota	15,000.00	15,000.00	356,746.48			43,057.98	
Mississippi	15,000.00	15,000.00	82,600.00	14,212.43	275.00	23,073.89	293.22
Missouri	15,000.00	15,000.00	36,024.38	7,193.33	25,285.92	19,952.34	
Montana	15,000.00	15,000.00	134,485.55	5,829.49		18,263.57	61.05
Nebraska	15,000.00	15,000.00	178,780.24				
Nevada	15,000.00	15,000.00	1,200.10	592.31		995.00	
New Hampshire	15,000.00	15,000.00	7,000.00	1,553.96		768.85	13,958.89
New Jersey (College)	15,000.00	15,000.00					
New Jersey (State)			155,817.51		49,060.36	31,796.39	
New Mexico	15,000.00	15,000.00	7,500.00	23,258.47		5,575.48	
New York (Cornell)	13,500.00	13,500.00	404,719.12			37,189.15	312.55
New York (State)[3]	1,500.00	1,500.00	211,950.55	5,379.58			
North Carolina	15,000.00	15,000.00	188,346.00			3,298.65	3,800.00
North Dakota	15,000.00	15,000.00	9,592.63	175,691.34		70,198.74	7,750.00
Ohio	15,000.00	15,000.00	252,015.00	70,157.95		35,367.98	1,068.65
Oklahoma[3]	15,000.00	15,000.00	10,500.00			8,073.54	
Oregon	15,000.00	15,000.00	92,000.00	51,214.63		26,474.95	4,000.00
Pennsylvania	15,000.00	15,000.00	27,584.09	2,668.74	469.72	18,365.52	5,237.04
Porto Rico							[2]50,000.00
Rhode Island	15,000.00	15,000.00	10,325.53	2,551.17		5,582.73	
South Carolina	15,000.00	15,000.00	64,849.18	1,417.51		24,754.41	
South Dakota	15,000.00	15,000.00	14,420.00	7,036.00		1,512.04	6,193.81
Tennessee	15,000.00	15,000.00	53,973.32			500.52	
Texas	15,000.00	15,000.00	197,985.00	4,410.24		72,722.99	
Utah	15,000.00	15,000.00	49,662.90			6,987.85	
Vermont	15,000.00	15,000.00				344.93	
Virginia	15,000.00	15,000.00	57,860.39	14,548.70		10,867.30	693.10
Virgin Islands							[2]20,000.00
Washington	15,000.00	15,000.00	105,276.61	11,076.30		49,893.76	
West Virginia	15,000.00	15,000.00	120,000.00	4,203.11		35,084.83	
Wisconsin	15,000.00	15,000.00	252,783.69			42,948.31	5,596.33
Wyoming	15,000.00	15,000.00	12,000.00	5,620.62		1,384.92	
Total	720,000.00	720,000.00	5,539,077.02	767,945.51	373,977.00	1,050,238.55	322,415.12

[1] Not including balances from Federal funds.
[2] Supported by direct appropriation to the United States Department of Agriculture.

to equipment, 1923

Revenue	Additions to equipment						
Total	Buildings	Library	Apparatus	Farm implements	Livestock	Miscellaneous	Total
$77,880.08	$3,170.63	$508.93	$1,532.77	$1,408.12	$1,439.60	$510.61	$8,570.66
75,000.00							
120,566.65	2,530.52		1,114.89	4,084.44	720.88	659.07	9,109.80
106,907.64			500.00	600.00	1,000.00	350.00	2,450.00
726,999.07	119,993.43	3,647.25	7,755.89	13,773.33	4,963.93	10,586.49	160,720.32
182,894.93	5,566.00	616.00	4,866.00	1,599.37	7,238.00	22,358.00	42,243.37
104,992.02	80.02	891.82	1,379.23	1,004.38		2,947.08	6,302.53
53,437.66	1,000.00	100.00	500.00	200.00			1,800.00
60,336.09		334.65	1,010.76	571.81	1,500.00	465.85	3,883.07
114,895.03	14,862.67	997.11	1,223.81	451.67	1,205.40	1,459.31	20,199.97
52,898.94	6,055.62	451.56	1,193.31	1,286.51	784.74		9,771.74
15,000.00							
50,000.00							
55,527.67	900.00	60.00	980.00	550.00	2,000.00	350.00	4,840.00
421,564.82	288,769.62					29,183.80	317,953.42
623,478.23	14,586.47	852.91	550.81	4,395.22	6,050.22	1,560.17	27,995.80
373,181.14			4,825.40	1,513.79	237.50		6,576.69
167,199.69	8,000.00	70.05	259.41	8,853.67	5,180.73	1,247.17	23,611.03
189,526.89		965.58	703.67	1,187.28	1,921.00	493.25	5,270.78
112,527.29	2,576.38	140.49	673.23	2,464.61	1,223.42	307.00	7,385.13
67,445.80		686.27	48.96	1,172.32		87.63	1,995.18
102,592.25	2,358.70	356.69	1,701.11	1,869.63	200.00	818.20	7,304.33
179,340.28	2,328.93	1,193.57	761.27	2,224.75	21.45	419.40	6,949.37
325,754.62	11,000.00	500.00	2,000.00	1,000.00	200.00		14,700.00
429,804.46	19,971.84	1,330.86	1,696.89	6,197.67	8,866.51	3,258.97	41,322.74
150,454.54	5,115.00	37.47	1,153.34	717.65	829.50	2,154.32	10,007.28
118,455.97	982.33	121.33	1,989.64	851.17	2,033.10	619.52	6,597.09
188,639.66	12,483.00	97.54	1,142.00	7,582.00	1,033.00	2,241.00	24,578.54
208,780.24	30,000.00	2,489.00		7,129.06	17,142.58	21,126.88	77,887.52
32,787.41	689.72	588.12	158.53	49.75	781.30	374.00	2,641.42
53,281.70	508.58	294.55	766.99	306.25		67.73	1,944.10
30,000.00	4,934.61	1,037.00	26,096.90	3,293.39	1,674.06	5,030.23	42,066.19
236,674.26							
66,333.95	1,407.72	127.74	413.43	1,146.62	1,009.17	496.60	4,601.28
469,220.82	204,255.35	915.96	10,172.15	1,610.83	509.25	1,452.66	218,916.20
220,330.13	3,500.00	1,200.00	3,600.00	1,700.00			10,000.00
225,444.65	18,931.18		241.95	4,442.10	1,175.80	589.49	25,380.52
293,232.71	10,000.00	137.97	280.28	7,412.91	9,875.35		27,706.51
388,609.58	16,472.84	682.73	767.42	847.53	4,815.15	5,032.01	28,617.68
48,573.54	4,000.00	1,244.66	678.23	322.56	264.10		6,509.55
203,689.58	4,345.07	116.11	60.00	1,039.46	9,284.84	4,644.06	19,489.54
84,325.11	25,000.00	693.14	4,261.27	2,472.67	3,078.11		35,505.19
50,000.00							
48,459.43	94.75	349.35	414.83	367.04	56.25	710.37	1,992.59
121,021.10	2,200.00	900.00	150.00	500.00	800.00	750.00	5,300.00
59,161.85		20.00	409.00	240.00	300.00		969.00
84,473.84	500.00	215.25	134.92	1,715.29	3,985.00	70.00	6,620.46
305,118.23	9,181.40	981.60	3,215.36	13,877.05	3,450.25	9,757.72	40,463.38
86,650.75		300.00	1,800.00	500.00		300.00	2,900.00
30,344.93		192.53	1,426.38	50.46	461.50		2,130.87
113,969.49	13,775.94	493.66	738.95	1,767.67	1,095.00	6,300.00	24,171.22
20,000.00							
196,246.67	5,281.99	545.59	298.40	3,892.12	685.30	666.34	11,369.74
189,287.94	21,471.22	428.28	216.77	3,884.28	3,088.85	954.63	30,044.03
331,328.33	9,285.67	1,393.18	4,844.86	5,943.28	5,696.76	4,920.73	32,084.48
49,005.54	19,925.62	1,075.00	316.74	838.64	3,111.25	2,845.32	28,112.57
9,493,653.20	928,092.82	30,381.50	101,025.75	130,908.35	120,988.85	148,165.61	1,459,562.88

[3] Including balances: New York (State), $0.41; Hatch; Oklahoma, $415.93 Hatch, $1,746.07 Adams.

Expenditures from United States appropriations received under the

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$15,000.00	$9,294.68	$1,228.15	$513.20	$370.00	$106.40	------	$187.67
Arizona	15,000.00	7,982.13	948.48	33.75	541.83	414.96	$86.03	559.72
Arkansas	15,000.00	8,265.00	1,567.93	1,018.67	377.07	413.25	287.36	116.48
California	15,000.00	15,000.00	------	------	------	------	------	------
Colorado	15,000.00	12,112.46	401.28	190.75	29.26	13.55	------	87.81
Connecticut (State)	7,500.00	7,500.00	------	------	------	------	------	------
Connecticut (Storrs)	7,500.00	7,500.00	------	------	------	------	------	------
Delaware	15,000.00	10,269.33	891.71	1,178.46	525.91	44.51	430.38	136.71
Florida	15,000.00	11,373.66	991.34	28.00	84.16	19.77	21.05	237.40
Georgia	15,000.00	8,476.63	3,159.59	33.00	479.83	182.90	688.87	------
Idaho	15,000.00	11,473.98	1,972.53	190.26	28.92	51.50	49.50	281.50
Illinois	15,000.00	14,962.53	------	------	32.81	------	------	------
Indiana	15,000.00	14,500.00	358.00	------	17.87	------	------	------
Iowa	15,000.00	8,415.00	752.92	462.96	259.54	------	189.17	149.87
Kansas	15,000.00	9,450.00	4,365.25	6.26	213.22	------	------	149.97
Kentucky	15,000.00	15,000.00	------	------	------	------	------	------
Louisiana	15,000.00	9,122.73	3,774.21	95.00	106.02	22.39	606.04	.50
Maine	15,000.00	6,402.51	3,520.68	90.94	400.80	267.69	853.54	6.54
Maryland	15,000.00	14,152.62	68.12	------	8.91	161.70	------	327.02
Massachusetts	15,000.00	12,980.00	1,442.13	------	------	------	------	1.31
Michigan	15,000.00	15,000.00	------	------	------	------	------	------
Minnesota	15,000.00	15,000.00	------	------	------	------	------	------
Mississippi	15,000.00	9,578.34	2,741.52	------	12.70	54.19	203.36	------
Missouri	15,000.00	10,389.04	1,766.91	------	105.97	136.11	44.44	169.11
Montana	15,000.00	14,655.00	2.00	224.72	118.28	------	------	------
Nebraska	15,000.00	15,000.00	------	------	------	------	------	------
Nevada	15,000.00	9,350.52	1,919.62	445.24	167.17	17.67	75.80	------
New Hampshire	15,000.00	10,251.00	644.75	1,198.50	209.66	263.67	600.00	198.10
New Jersey	15,000.00	10,282.16	823.23	630.32	188.27	3.62	455.34	454.06
New Mexico	15,000.00	5,793.13	3,561.23	1,450.83	172.64	171.04	233.79	65.06
New York (State)[1]	1,500.00	424.94	1,075.06	------	------	------	------	------
New York (Cornell)	13,500.00	8,875.00	1,986.14	------	16.25	12.00	114.13	1,137.00
North Carolina	15,000.00	9,738.04	1,891.17	------	118.73	59.65	86.30	228.13
North Dakota	15,000.00	15,000.00	------	------	------	------	------	------
Ohio	15,000.00	13,075.29	648.29	------	133.00	9.76	690.00	31.21
Oklahoma	15,000.00	6,627.23	1,980.83	1,244.88	227.43	272.08	71.69	431.81
Oregon	15,000.00	11,599.00	2,746.14	208.85	22.63	37.67	21.15	80.24
Pennsylvania	15,000.00	11,800.00	311.81	1,819.05	28.68	84.80	6.48	26.75
Rhode Island	15,000.00	5,129.53	4,708.30	1,326.25	231.62	258.79	343.87	1.80
South Carolina	15,000.00	8,638.32	1,394.17	88.85	419.13	362.07	12.00	28.83
South Dakota	15,000.00	8,261.58	1,463.54	3,202.20	34.00	77.98	------	382.20
Tennessee	15,000.00	11,395.12	904.25	202.31	332.77	118.60	757.20	145.90
Texas	15,000.00	14,141.05	------	------	39.76	------	------	------
Utah	15,000.00	12,120.67	1,275.47	------	17.16	50.86	------	30.66
Vermont	15,000.00	8,131.02	1,663.74	1,605.40	279.68	30.42	810.75	113.43
Virginia	15,000.00	10,195.97	3,099.69	------	156.63	112.42	23.01	36.21
Washington	15,000.00	9,227.16	2,518.10	1,232.30	10.13	------	------	.93
West Virginia	15,000.00	9,000.00	1,570.39	26.42	------	57.64	------	104.34
Wisconsin	15,000.00	10,564.66	2,151.25	122.51	------	------	------	919.92
Wyoming	15,000.00	10,610.00	1,225.33	165.47	------	------	148.35	195.34
Total	720,000.00	524,087.03	69,515.25	19,035.35	6,518,44	3,889.66	7,909.60	7,023.53

[1] Including a balance of $0.41.

act of March 2, 1887 (Hatch Act) for the year ended June 30, 1923

Classified expenditures											
Seeds, plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
$342.58	$357.89	$554.87	$346.42	$202.03	$234.03	$346.46	$669.10	$133.80	$5.20	$107.52	-------
359.41	37.70	2,198.47	-------	460.08	70.60	658.50	162.00	455.79	10.00	20.55	-------
1,253.01	116.14	625.29	15.00	320.59	2.52	11.37	141.38	423.04	-------	45.90	-------
275.25	-------	254.93	71.35	-------	53.50	325.82	28.00	451.33	-------	704.71	-------
335.28	12.90	-------	323.84	59.72	340.19	4.80	-------	323.22	17.50	105.54	-------
197.27	349.93	499.95	243.24	92.45	175.11	31.32	-------	363.00	.58	291.76	$0.01
430.40	477.80	150.88	338.24	388.69	19.64	7.48	2.25	149.80	-------	14.00	-------
212.39	90.00	56.20	-------	53.42	-------	65.18	-------	359.52	-------	115.10	-------
				4.66							
4.53	1.63	-------	-------	-------	-------	-------	-------	117.97	-------	-------	-------
427.38	-------	4,147.26	-------	39.04	2.80	1.21	-------	143.71	-------	9.14	-------
192.31	-------	-------	-------	208.39	30.00	59.09	-------	307.51	-------	18.00	-------
247.51	-------	381.25	27.00	54.30	14.50	-------	-------	395.11	-------	153.44	-------
496.76	179.46	1,467.35	565.09	16.47	120.77	10.67	-------	406.77	-------	193.96	-------
22.67	-------	-------	-------	1.43	21.80	232.55	-------	3.18	-------	-------	-------
167.34	321.97	-------	-------	52.25	-------	-------	35.00	-------	-------	-------	-------
826.92	124.88	1,248.00	-------	163.73	-------	-------	-------	-------	-------	46.36	-------
590.35	82.33	1,187.32	17.00	95.75	5.12	141.87	78.30	131.50	-------	58.88	-------
340.55	-------	120.52	514.23	254.83	203.21	2.18	30.00	995.46	-------	563.00	-------
204.26	149.02	-------	294.55	101.91	56.43	187.50	-------	639.61	-------	1.04	-------
396.44	-------	300.00	4.00	45.75	30.87	16.00	-------	1,259.11	3.50	107.33	-------
486.06	202.42	597.02	30.30	564.33	154.55	8.89	573.72	458.74	-------	476.25	-------
401.21	33.50	-------	40.48	245.39	253.30	157.15	-------	-------	-------	228.45	-------
174.27	658.42	699.16	-------	-------	-------	-------	440.00	156.13	-------	750.00	-------
124.30	288.15	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
480.89	11.39	1,159.28	744.66	294.91	34.00	379.24	114.30	446.45	-------	63.00	415.93
116.96	-------	-------	-------	-------	-------	25.76	-------	141.60	-------	-------	-------
489.22	88.86	6.25	-------	48.67	11.69	12.96	-------	202.51	-------	62.27	-------
424.08	1,016.47	349.49	433.42	260.59	30.24	13.05	-------	231.06	-------	241.44	-------
330.98	401.94	705.03	824.94	214.59	750.92	1.29	10.60	151.21	-------	665.13	-------
277.19	-------	421.86	-------	203.00	110.00	198.35	-------	139.62	-------	228.48	-------
145.76	30.25	-------	264.31	136.94	74.64	42.61	-------	244.98	-------	204.36	-------
				161.09	242.00	-------	-------	-------	-------	416.10	-------
403.32	-------	97.23	22.40	31.75	17.27	-------	180.00	753.21	-------	-------	-------
1,055.55	84.91	-------	159.19	86.46	-------	19.14	-------	486.39	-------	473.92	-------
511.28	320.69	2.98	160.55	192.72	45.84	35.06	-------	9.20	-------	97.75	-------
354.59	68.76	-------	-------	134.40	50.05	8.01	-------	1,395.57	-------	-------	-------
1,372.69	86.45	-------	-------	872.09	404.58	626.39	-------	879.01	-------	-------	-------
378.06	33.43	-------	-------	-------	-------	718.58	-------	111.59	-------	-------	-------
120.25	54.00	1,954.37	-------	328.90	59.15	27.30	-------	44.00	48.00	19.54	-------
14,969.27	5,681.29	19,184.96	5,440.21	6,391.32	3,619.32	4,375.78	2,464.65	12,910.70	84.78	6,482.92	415.94

Expenditures from United States appropriations received under the

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies	Seeds, plants, and sundry supplies
Alabama	$15,000.00	$10,966.66	$830.94	$27.70	$77.65		$768.01	$262.43
Arizona	15,000.00	12,397.87	347.40	191.59	86.99		165.73	76.62
Arkansas	15,000.00	9,465.00	2,861.47	129.30	114.49	$236.60	507.63	383.20
California	15,000.00	11,615.00	872.04	67.93		159.01	450.03	570.52
Colorado	15,000.00	13,232.96	62.35	2.95	18.33		703.18	53.28
Connecticut (State)	7,500.00	7,500.00						
Connecticut (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	11,845.65	494.33	15.10	61.37		1,005.71	265.49
Florida	15,000.00	13,750.00	168.14	20.38	46.22	7.80	282.38	54.14
Georgia	15,000.00	10,920.00	152.98		210.99	504.64	884.69	21.69
Idaho	15,000.00	11,320.58	1,609.17	17.55	300.44	212.50	321.61	109.45
Illinois	15,000.00	13,332.47	1,574.98					
Indiana	15,000.00	11,460.00	375.79	99.01			646.63	719.37
Iowa	15,000.00	9,395.00	2,772.38	112.89		110.85	821.79	442.01
Kansas	15,000.00	10,550.00	2,885.60	2.25	8.80	.50	96.38	119.33
Kentucky	15,000.00	15,000.00						
Louisiana	15,000.00	13,374.94	765.00	23.87	25.53	260.10	160.82	115.14
Maine	15,000.00	14,716.56		52.00	2.14			69.73
Maryland	15,000.00	13,261.72	12.09	27.00		196.17	406.93	42.59
Massachusetts	15,000.00	14,631.00	310.31				21.92	5.95
Michigan	15,000.00	15,000.00						
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	10,563.52	1,456.36	4.43	118.80	105.16	1,321.33	581.49
Missouri	15,000.00	6,018.25	1,638.79	28.23	207.77	176.91	864.97	406.95
Montana	15,000.00	10,444.68	2,189.21	3.90	40.34		486.46	238.30
Nebraska	15,000.00	15,000.00						
Nevada	15,000.00	8,868.00	3,180.10	10.78	129.40	298.25	325.79	117.84
New Hampshire	15,000.00	11,110.00	1,302.05	6.30	82.37		455.43	174.27
New Jersey	15,000.00	12,290.51	357.23	11.99	4.75	869.66	696.94	62.29
New Mexico	15,000.00	8,986.48	2,524.32	84.61	226.63	161.86	902.26	230.11
New York (State)	1,500.00	1,500.00						
New York (Cornell)	13,500.00	9,875.00	3,608.24	6.10			8.04	
North Carolina	15,000.00	13,433.29	1,055.06	119.76	15.78	94.30	25.95	
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	14,047.92	759.72				31.76	54.60
Oklahoma	15,000.00	11,299.68	1,018.62				440.76	97.38
Oregon	15,000.00	12,960.35	379.56	2.21	116.03	32.29	962.69	136.49
Pennsylvania	15,000.00	10,679.00	285.76	5.37	84.56	5.80	796.90	75.41
Rhode Island	15,000.00	9,349.50	3,063.95	29.39	19.51	725.82	91.32	56.55
South Carolina	15,000.00	10,448.22	2,096.94	46.33	25.27	229.44	201.56	200.28
South Dakota	15,000.00	8,988.24	4,119.79	106.65	12.47		282.11	448.21
Tennessee	15,000.00	13,450.00	197.45	29.55	58.79	234.22	451.60	58.86
Texas	15,000.00	14,182.05	420.00			16.50	125.16	170.59
Utah	15,000.00	9,596.07	3,668.23	54.25	31.95		479.45	193.73
Vermont	15,000.00	8,473.32	3,019.47	80.70	6.44	62.17	202.07	251.58
Virginia	15,000.00	9,449.88	3,157.03	1.25	100.19	20.06	176.83	375.73
Washington	15,000.00	12,602.90	1,068.06	.82		58.32	375.54	188.19
West Virginia	15,000.00	10,600.00	629.43	28.52			271.17	727.11
Wisconsin	15,000.00	10,209.88	3,453.80		3.22		266.44	131.89
Wyoming	15,000.00	12,856.07	335.65	5.55	28.13		234.36	30.34
Total	720,000.00	568,428.22	61,089.79	1,456.21	2,265.35	4,778.93	17,720.33	8,319.13

act of March 16, 1906 (Adams Act) for the year ended June 30, 1923

Classified expenditures										
Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
----------	$139.10	$123.41	$141.89	$8.50	$949.13	$244.00	$125.90	----------	$334.68	----------
----------	----------	----------	405.89	54.25	456.39	----------	805.27	----------	12.00	----------
103.30	275.85	----------	501.98	54.05	66.42	23.15	257.11	----------	20.45	----------
----------	186.35	25.85	279.26	60.95	199.16	217.68	189.57	----------	106.65	----------
----------	33.27	8.00	----------	8.50	681.38	----------	195.80	----------	----------	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
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39.00	----------	10.81	102.24	55.00	826.85	----------	278.45	----------	----------	----------
215.00	----------	2.40	28.21	17.80	57.90	----------	318.75	----------	30.88	----------
100.00	1,085.19	70.67	30.84	----------	247.40	604.74	166.17	----------	----------	----------
----------	128.75	----------	231.45	----------	19.38	----------	652.82	----------	76.30	----------
----------	45.10	----------	----------	----------	12.45	35.00	----------	----------	----------	----------
13.90	29.86	----------	207.70	8.59	293.85	969.65	175.65	----------	----------	----------
----------	588.66	----------	334.40	----------	----------	----------	275.77	----------	146.25	----------
----------	352.97	----------	301.78	25.45	6.16	472.85	175.27	----------	2.66	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	163.60	70.89	----------	----------	3.15	----------	36.96	----------	----------	----------
----------	----------	----------	----------	----------	----------	----------	159.57	----------	----------	----------
----------	----------	5.40	161.81	5.90	740.07	----------	120.25	----------	20.07	----------
----------	----------	----------	----------	20.25	10.57	----------	----------	----------	----------	----------
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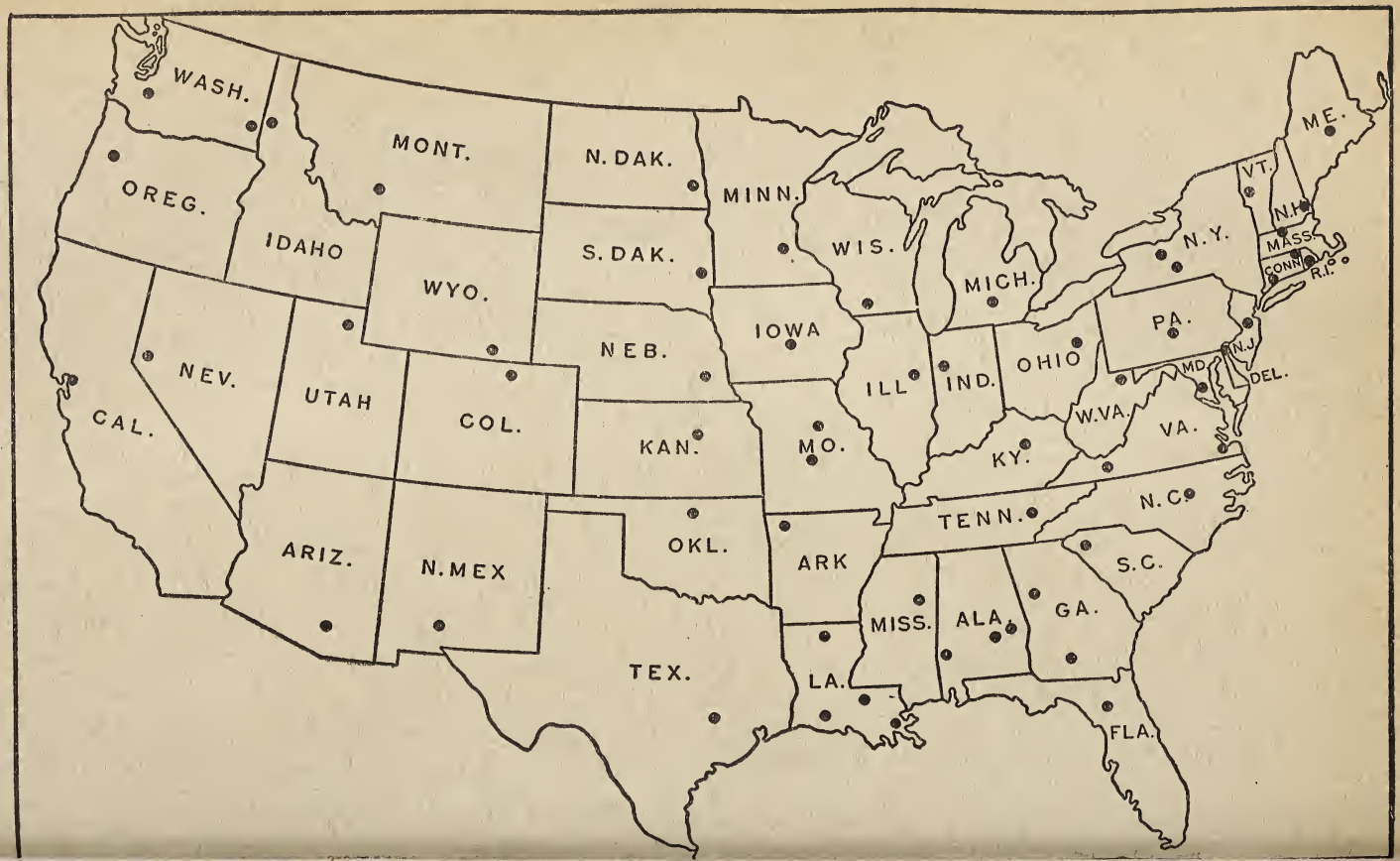
----------	----------	44.31	394.37	1.20	142.37	----------	266.66	----------	----------	----------
13.24	3,799.73	----------	127.47	12.01	1,185.73	175.05	----------	----------	344.90	----------
----------	----------	58.66	255.37	11.53	864.30	----------	407.25	----------	----------	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	740.88	27.00	41.35	----------	43.46	794.15	423.00	----------	----------	----------
----------	551.58	----------	204.34	11.30	579.49	----------	15.33	----------	507.54	----------
----------	60.00	9.00	47.75	29.26	402.18	----------	40.55	$60.75	147.14	----------
248.32	263.80	18.35	416.58	142.17	361.83	70.00	22.52	----------	340.16	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	----------	----------	----------	----------	2.62	----------	----------	----------	----------	----------
140.98	----------	----------	----------	----------	26.91	----------	87.97	----------	----------	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	6.00	----------	----------	----------	90.00	----------	----------	----------	----------	----------
52.50	18.35	----------	27.65	----------	298.99	----------	----------	----------	----------	$1,746.07
----------	4.20	28.07	226.00	----------	102.45	----------	48.90	.76	----------	----------
2.50	103.28	156.43	11.67	27.88	2,380.30	19.35	104.65	----------	261.14	----------
----------	1,121.68	45.20	45.55	----------	10.00	10.00	5.05	----------	426.48	----------
200.00	15.00	2.06	308.73	600.00	626.17	----------	----------	----------	----------	----------
30.00	128.40	26.49	49.07	154.55	292.12	4.00	302.06	----------	55.84	----------
1.30	----------	31.49	118.73	26.60	96.50	----------	220.91	----------	24.00	----------
----------	----------	----------	----------	----------	40.00	----------	45.70	----------	----------	----------
----------	----------	25.50	47.61	111.36	393.79	----------	306.85	----------	91.21	----------
----------	170.88	1.34	21.00	----------	1,323.65	461.50	175.88	----------	750.00	----------
310.00	495.63	----------	101.68	----------	533.80	----------	92.76	----------	185.16	----------
----------	263.51	----------	20.00	----------	223.21	49.00	150.45	----------	----------	----------
----------	74.17	6.00	275.06	51.00	1,426.80	----------	910.74	----------	----------	----------
----------	822.85	----------	4.50	----------	71.42	36.00	----------	----------	----------	----------
----------	915.18	----------	29.80	237.17	----------	70.25	217.63	----------	39.87	----------
1,470.04	12,583.82	797.33	5,501.73	1,735.27	16,088.35	4,256.37	7,778.17	61.51	3,923.38	1,746.07

Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906

State or Territory	Hatch Act		Adams Act	
	1888–1922	1923	1906–1922	1923
Alabama	$523,956.42	$15,000.00	$221,619.89	$15,000.00
Arizona	489,803.10	15,000.00	224,955.61	15,000.00
Arkansas	523,139.12	15,000.00	224,900.00	15,000.00
California	525,000.00	15,000.00	224,926.84	15,000.00
Colorado	524,718.82	15,000.00	223,638.93	15,000.00
Connecticut	525,000.00	15,000.00	225,000.00	15,000.00
Dakota Territory	56,250.00			
Delaware	523,382.87	15,000.00	220,475.12	15,000.00
Florida	524,966.06	15,000.00	224,996.06	15,000.00
Georgia	520,593.43	15,000.00	212,092.87	15,000.00
Idaho	449,324.13	15,000.00	220,842.22	15,000.00
Illinois	524,564.95	15,000.00	224,851.62	15,000.00
Indiana	524,901.19	15,000.00	225,000.00	15,000.00
Iowa	525,000.00	15,000.00	225,000.00	15,000.00
Kansas	524,995.00	15,000.00	225,000.00	15,000.00
Kentucky	524,996.57	15,000.00	225,000.00	15,000.00
Louisiana	525,000.00	15,000.00	225,000.00	15,000.00
Maine	524,999.62	15,000.00	225,000.00	15,000.00
Maryland	524,967.40	15,000.00	224,236.48	15,000.00
Massachusetts	524,617.70	15,000.00	225,000.00	15,000.00
Michigan	524,676.10	15,000.00	221,341.20	15,000.00
Minnesota	524,917.78	15,000.00	224,345.00	15,000.00
Mississippi	525,000.00	15,000.00	225,000.00	15,000.00
Missouri	520,097.24	15,000.00	224,999.90	15,000.00
Montana	435,000.00	15,000.00	222,417.04	15,000.00
Nebraska	524,932.16	15,000.00	225,000.00	15,000.00
Nevada	524,214.32	15,000.00	223,180.28	15,000.00
New Hampshire	525,000.00	15,000.00	225,000.00	15,000.00
New Jersey	524,949.97	15,000.00	224,392.06	15,000.00
New Mexico	489,509.05	15,000.00	225,000.00	15,000.00
New York	524,757.59	14,999.59	224,463.01	15,000.00
North Carolina	525,000.00	15,000.00	210,000.00	15,000.00
North Dakota	466,502.26	15,000.00	224,638.85	15,000.00
Ohio	525,000.00	15,000.00	223,514.02	15,000.00
Oklahoma	449,568.96	14,584.07	206,360.56	13,253.93
Oregon	510,156.64	15,000.00	220,000.00	15,000.00
Pennsylvania	524,967.43	15,000.00	224,995.41	15,000.00
Rhode Island	525,000.00	15,000.00	222,464.20	15,000.00
South Carolina	524,542.15	15,000.00	223,460.12	15,000.00
South Dakota	468,250.00	15,000.00	220,000.00	15,000.00
Tennessee	525,000.00	15,000.00	225,000.00	15,000.00
Texas	525,000.00	15,000.00	222,592.26	15,000.00
Utah	390,000.00	15,000.00	224,821.94	15,000.00
Vermont	525,000.00	15,000.00	225,000.00	15,000.00
Virginia	522,824.12	15,000.00	224,949.01	15,000.00
Washington	462,102.65	15,000.00	221,080.11	15,000.00
West Virginia	524,968.71	15,000.00	222,859.12	15,000.00
Wisconsin	525,000.00	15,000.00	225,000.00	15,000.00
Wyoming	510,000.00	15,000.00	225,000.00	15,000.00
Total	24,582,113.51	719,583.66	10,704,409.73	718,253.93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